Teaching BIM Code Compliance through Interdisciplinary Student Collaboration

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Abstract- This paper describes an experimental classroom experience at The University of Southern Mississippi in which Master's level Construction Management students and undergraduate Computer Science students collaborated to produce a prototype of excavation workflow based on Occupational Safety and Health Administration (OSHA) and United States Army Corp of Engineers (USACE) standards. The Construction Management students met with subject experts from the ERDC CAD-BIM center and applied their expertise to develop extensive flowcharts for OSHA and USACE earthwork code compliance. These flowcharts included building and site information that could be retrieved automatically from BIM electronic documents as well as workflow for gathering required input and paperwork from various types of construction professionals. The undergraduate students in the Computer Science class, "Process Engineering", prepared for the joint classroom exercise by studying "workflow engines" which are used to implement large numbers of sequential or dependent activities. The two sets of students then met to finalize the requirements encoded as earthworks code compliance flowcharts. The Computer Science students then developed an automated workflow that matched the specification developed by the construction students.

This paper discusses this unique interaction between Construction Management students and Computer Science students to work on BIM Code compliance that allowed Construction Management students to gain a valuable experience by (1) learning the earthwork rules in a highly systematic way, (2) considering code compliance data that could be derived from or input into a BIM model and (3) interacting with the Computer Science students who had a fundamentally different way of approaching the exact specification of rules and workflow. On the other hand, this interaction allowed Computer Science students to gain a valuable experience by (1) working on a real world application of process workflow, (2) learning about Building Information Model (BIM) software and considering the properties that could be automatically calculated from BIM data and (3) participating in elicitation exercises with the Construction Management students who had real world knowledge to make complex OSHA and USACE codes understandable.

Keywords: Construction Management, BIM, Code Compliance, Collaboration, Teaching, Software Engineering

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Introduction

Students in Construction Management generally learn about Earthworks code compliance through series of textbook paper and pencil exercises learning about various safety code or recommendations such as those shown in Figure 1. This provides raw information but does little to prepare students for the actual jobsite decision making process, which involves series of calculations and decisions applying the codes and/or safety rules they have learned in a systematic way.

Material	Bucket Fill Factor
Common earth, loam	0.80-1.10
Sand and gravel	0.90-1.00
Hard clay	0.65-0.95
Wet clay	0.50-0.90
Rock, well blasted	0.70-0.90
Rock, poorly blasted	0.40-0.70

1. Apply OSHA slope ratio to determine dimensions of excavation boundary at ground surface. This provides all dimensions required to calculate the absolute volume of the excavation.

Figure 1: Typical Earthworks paper and pencil exercise.

Similarly, Computer Science students typically learn various Software Engineering skills through application to imaginary problems without real "clients" or actual deliverables. Figure 2 shows a typical student project from "Process Engineering", the Software Engineering study of organizational process software development.

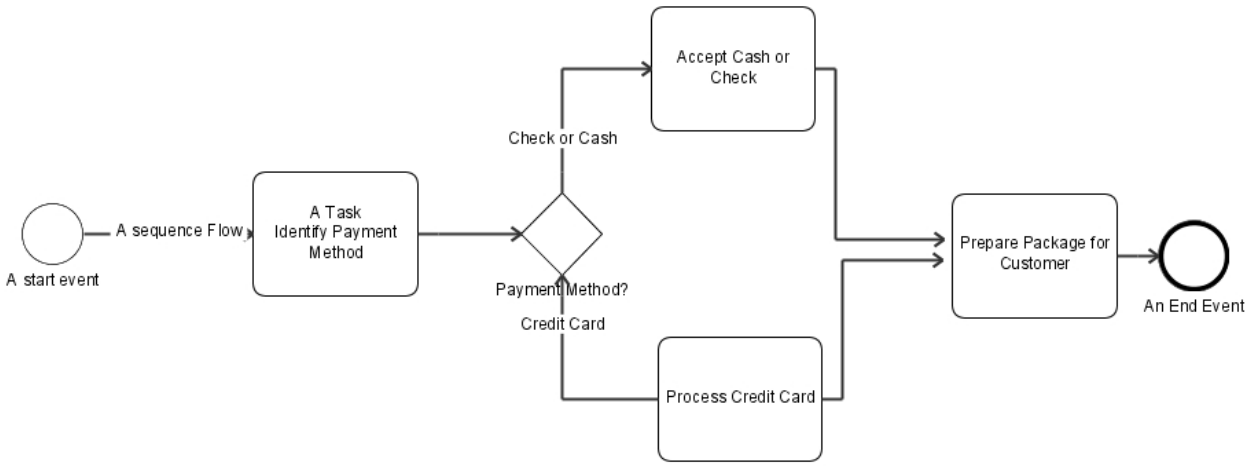

Figure 2: Typical "Imaginary" Process Engineering exercise.

This paper describes an experimental semester-long classroom experience at The University of Southern Mississippi in which Master's level Construction Management students and undergraduate Computer Science students collaborated to produce a prototype of excavation workflow based on OSHA and USACE standards. The objectives of the experiment where (1) to provide Construction Management students with a more structured and practical learning experience in which they considered the set of standards as complete body of knowledge to be followed step by step as laid out in a flow chart and (2) to provide Computer Science students with a more focused process development experience with real clients and a real product to be implemented using real world professional development tools.

Background

In Construction Management, excavating is recognized as one of the most hazardous construction operation [1] Therefore, OSHA has established a set of standards to increase the safety of jobsites to protect the workers. The standards includes a wide range of elements including but not limited to: Soil classification, test equipment, shorting types, shielding types, sloping, benching as well as special health and safety considerations. In addition to the OSHA Technical Manual, the USACE also uses their internal Safety and Health Requirements Manual. The purpose of this manual is to prescribe the safety and health requirements for all Corps of Engineers activities and operations [2]. It is important to highlight that the USACE standards indicates that where more stringent safety and occupational health standards are set forth, the more stringent standards shall apply.

Although significant effort are placed to reduce the risk of excavation, U.S. Bureau of Labor Statistics (BLS) data show that 271 workers died in trenching or excavation cave-ins from 2000 through 2006. A review of multiple national databases by NIOSH researchers found that trenching and excavation hazards during construction activities resulted in 488 deaths between 1992 and 2000 - an average of 54 fatalities each year. Sixty-eight percent of those fatalities occurred in companies with fewer than 50 workers. Forty-six percent of the deaths occurred in small companies with 10 or fewer workers [3].

On the other hand, Software Engineering is a very rapidly evolving field with numerous tools and techniques to be presented to students as they learn about the software life cycle. However, a growing body of research has indicated that the focus on abstract concepts underlying various Software Engineering tools does not prepare students for real world software development [4, 5, 6]. In the recent review article the author laments that Software Engineering education has been "...focused largely on SE's engineering aspects, at the expense of its human and social dimensions." [4] The ultimate solution to this problem is to present Software Engineering tools in the context of a real problem with real "clients" and delivery requirements which gives the students both the abstract conceptual understanding of the tools presented and also a better understanding of the human and social dimensions of software development.

One required element for Software Engineering students is that they learn one or more workflow development software's or engines. Workflow engines are very widely used in industry to

develop software which supports complex sets of interlocking and dependent activities, for example a set of web pages which leads the user through applying for a car loan. Workflow has primarily been taught through abstract exercises which focus on competent use of the tool through imaginary sets of problems such as the "car loan problem". This is satisfactory for learning the use of the tool's functions but does not provide the student with practical understanding of the most difficult and critical aspect of workflow development which is the human element: understanding the client's needs and absorbing their area knowledge to be able to iteratively develop a workflow which meets the client's exact needs.

In the classroom experiment described in this paper students learned about Windows Workflow Foundation [7], perhaps the most widely used professional workflow engine, through the direct application to the flowcharts developed by the cooperating class of Construction Management students. This experience was often frustrating for the Computer Science students who did not understand any of the terminology, jargon and underlying concepts of earthworks excavation. The Computer Science students were forced to quickly absorb CAD/BIM software concepts and had to lean upon the understanding of the Construction Management students' to comprehend and interpret complex safety rules. But, this classroom exercise provided a much richer, more realistic learning experience which covered both technical expertise and the human and social aspects of Construction Management and Software Engineering. The Construction Management group was composed of nine students with very little previous programming experience but some BIM Experience. On the other hand the Software Engineering group was composed of seven students with extensive programming experience but no BIM experience as shown in Figure 3.

Class	Number of Students	Computer Programming Experience	Previous BIM Experience
Construction Management	9	0-1 years	1 – 3 years
Process Engineering	7	2–5 years	none

Figure 3: Construction and Computer Student Groups.

Code Compliance Exercise

The Construction Management students initiated the exercise by identifying and reading several earthwork codes as they would do in a traditional classroom. Then they met with various OSHA subject experts from the USACE - Research and Development Center – Computer Aided Drafting/Building Information Modeling (ERDC CAD-BIM) center and discussed practical implementations of the codes. Based on the acquired knowledge (from the code and the discussions) the students developed extensive flowcharts for OSHA and USACE codes. The flowcharts included required safety information that could be retrieved automatically from BIM electronic documents and from construction professionals. (Sample of an OSHA Flowchart Segment Prepared by Construction Students is shown in Figure 4).

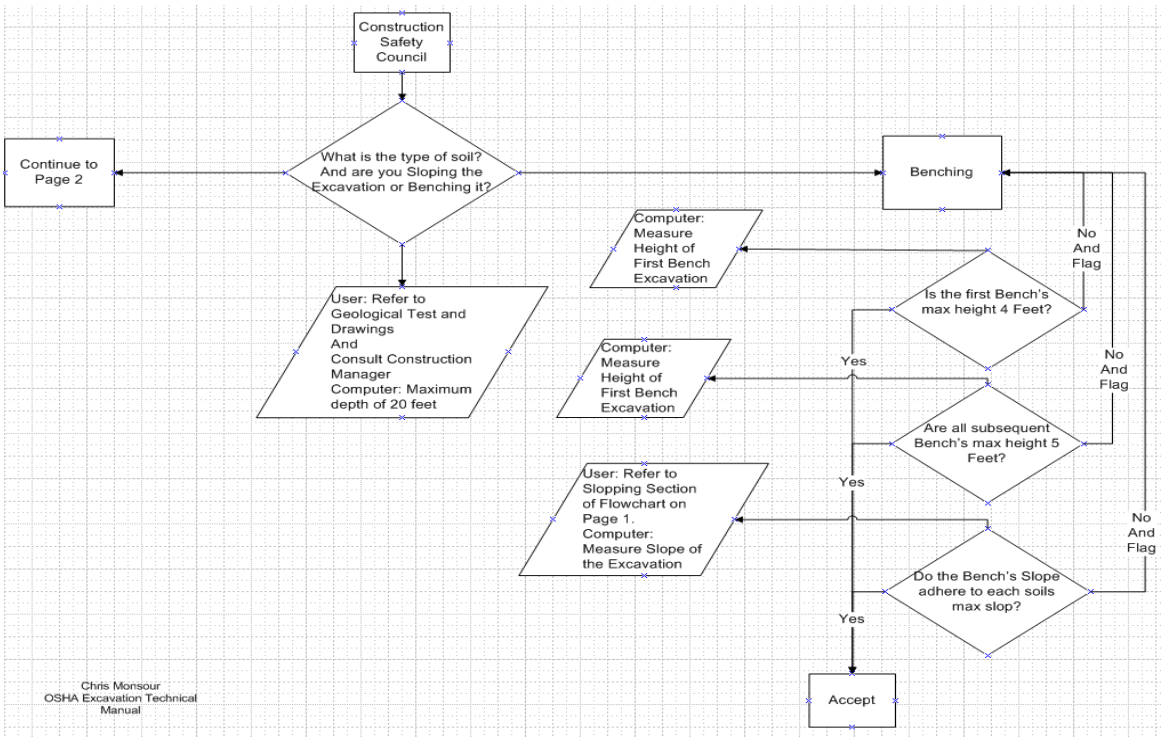

Figure 4: Sample OSHA Flowchart Segment Prepared by Construction Students.

After the Construction Management Students completed the first phase of the flowcharts, a meeting was arranged with the Computer Science students. The two main objectives of the meeting were for both groups to 1- Exchange expertise and 2- Identify additional work needed to develop an automatic BIM system for earthwork. The automatic BIM system is a program that first extracts autonomously from the BIM models various parameters such as footprints, topography, utilities, height and other information required as input to meet code requirements during the excavation process. After this information is extracted autonomously, the automatic BIM system workflow, takes the construction manager through the steps to ensure code compliance requesting additional information such as personnel certifications, identification of special hazardous situations and other compliance requirements. Fundamentally, the automatic BIM system is a an 'expert system' which combines the knowledge of the Construction Management students with the programming expertise of the Computer Science students which is both a potentially useful tool and a more systematic way of view code compliance. However, it was evident in the meeting that both groups of students have a total different view of the automatic BIM System. The Construction Students saw the system as a series of pieces of information and decisions in the code that they can obtain in a dynamic way either from a person or an electronic file. On the other hand, computer students saw the system as a series of sequential decisions for which information needed to be entered in advanced by a person or extracted from a file.

After the meeting both groups of students continue working in parallel. The Construction Management students focused on improving the flowchart and Computer Science students developed a prototype rules engine based on the flowchart that was developed by the construction students. Upon completing the flowcharts, the construction students gave them to the computer science students to complete the prototype. This prototype was then presented to

the construction students and the experts from ERDC CAD-BIM from the first meeting to provide additional comments and suggestions to improve the application.

BIM Code Compliance through Workflow Implementation

The Computer Science students initiated the exercise by learning Business Process Management Notation (BPMN) [8] a flow chart format which encodes regular activities as modular units as shown in Figure 5 using as their subject area the code compliance.

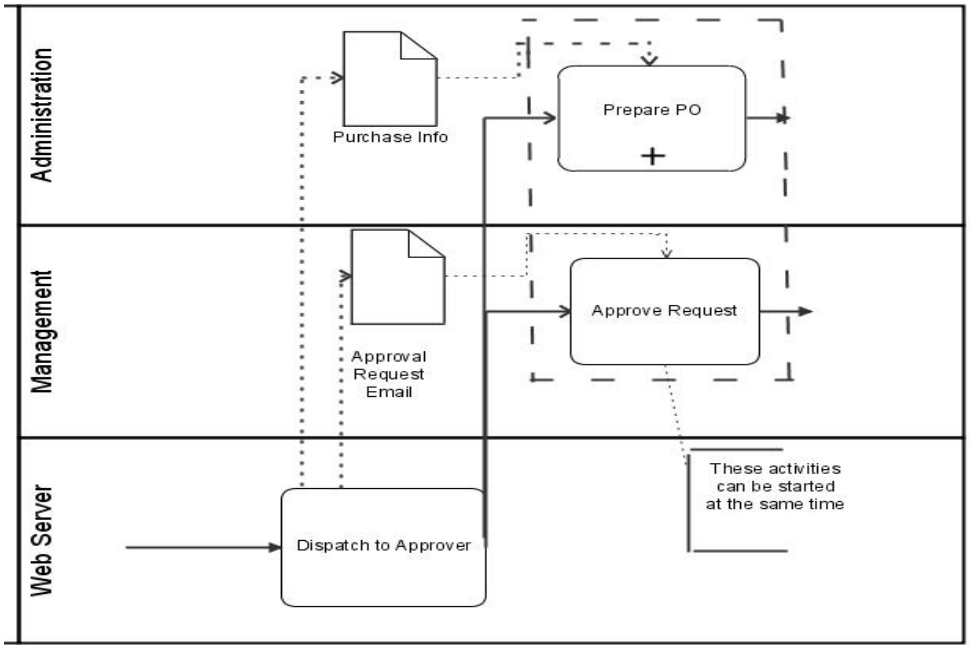

Figure 5: Student Exercise in Business Process Management Notation

Once BPMN flowchart notation was mastered, then students began to work with a workflow engine - Windows Workflow Foundation which allows the programmer to develop workflow software by dragging and dropping workflow elements such as decisions and processes onto a design palette as shown in Figure 6.

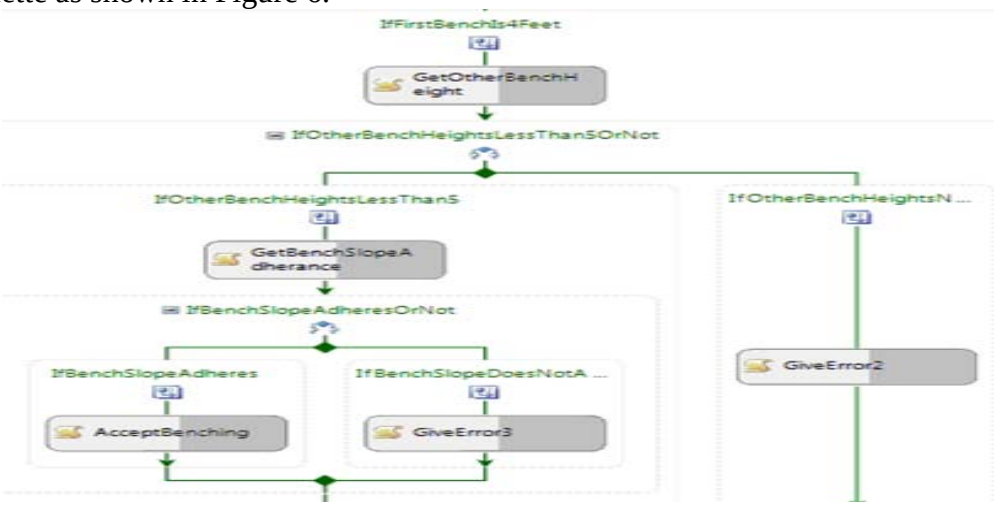

Figure 6 : Flowchart drag and drop interface in Microsoft Windows Workflow Foundation

The code generated by the Windows Workflow Foundation produces an application which supports the desired workflow designed by the Construction Management students for code compliance. For example, Figure 7 shows a window requesting depth information and soil type found on the site that will be used to determine several characteristics of the excavation such as slope to comply with OSHA regulation.

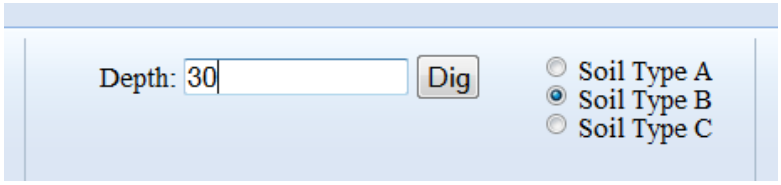

Figure 7. Interface Automatically Generated from Workflow

The Computer Science students were able to complete large sections of code compliance workflow because there is a natural one-to-one correspondence between flow charts of compliance rules and implementation of the rules in Windows Workflow Foundation as shown in figure 8.

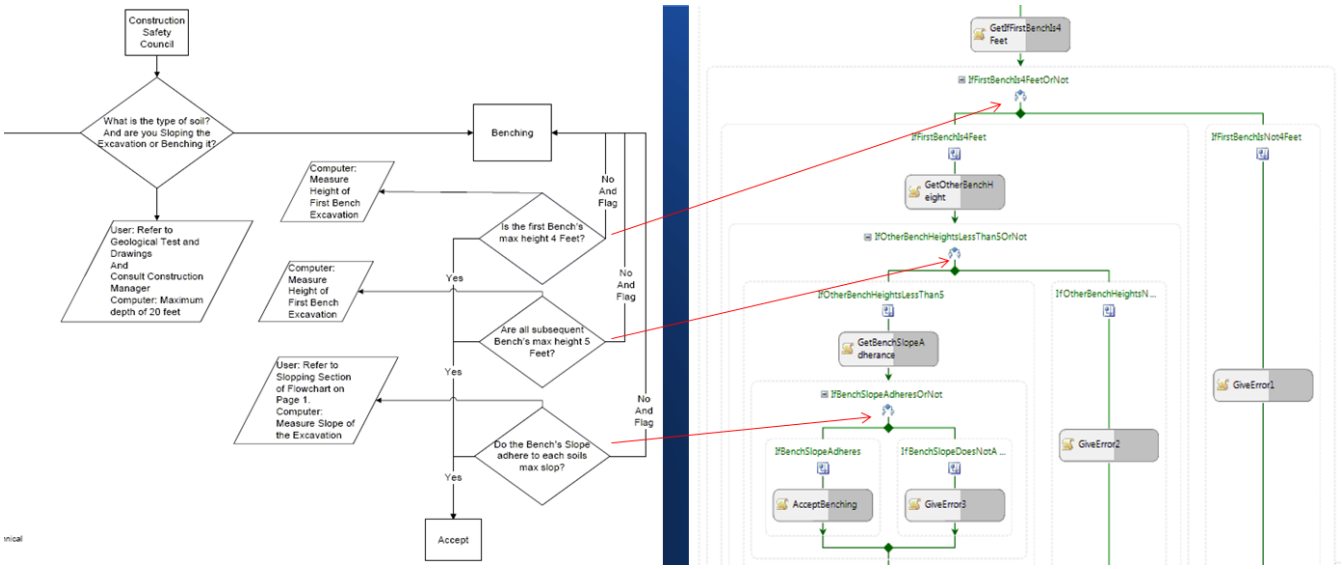

Figure 8: Correspondence between Code Compliance flowcharts developed by Construction management students (on the left) and Windows Workflow Foundation Implementations developed by Software Engineering students (on the right).

Students were able to complete six full section of the OSHA handbook on excavation, one section of USACE guidelines and one set of local guidelines with both detailed flowcharts from the Construction Management students and working workflow implementations from the Computer Science students. This class room experiment required the Construction Students to consider code compliance in a far more systematic and complete form closer to the level of detail necessary for real life compliance. The Computer Science students reached their learning objectives to become competent with workflow programming and development with a total more than 10,000 lines of high quality coding and an experience much closer to the real world

experience of working with clients in diverse fields and developing applications to meet specific requirements.

Summary

The construction management students gained a valuable experience by (1) learning the earthwork rules in a highly systematic way, (2) considering code compliance data that could be derived from or input into a BIM model and (3) interacting with the Computer Science students who had a fundamentally different way of approaching the exact specification of rules and workflow. Computer Science students gained a valuable experience by (1) working on a real world application of process workflow, (2) learning about Building Information Model (BIM) software and considering the properties that could be automatically calculated from BIM data and (3) participating in elicitation exercises with the Construction Management students who had real world knowledge to make complex OSHA and USACE codes understandable. This paper discusses the learning objectives, exercises, results and lessons learned from this unique classroom experiment.

Acknowledgement

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