NEW DESIGN MODEL FOR CAPSTONE DESIGN PROJECT AT CHRISTIAN BROTHERS UNIVERSITY

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Abstract

Capstone design project in the Department of Civil and Environmental Engineering (CEE) at Christian Brothers University is implemented through two semester courses (CE 431 and CE 432). All students are required to take these courses in their senior year to fulfill graduation requirements. Because students had a difficult time finding the topic of their projects and completing their projects in time, the CEE Department teamed up with governmental and private practitioners to develop a series of strategies and to extend senior project from two semesters to three semesters. As a result, students will have more time and better management skills to organize their projects, find topics, layout design components, and work with practitioners. Since this change started in 2014, the graduation rate has improved from 65% to 96%. This paper will present this new design model of the capstone project including, planning stage, project development, project implementation, and final assessment.

Keywords

Capstone project, senior project, project management, curriculum improvement

Introduction

Capstone design project is one of the core courses in the engineering curriculum, which has been widely used to assess student's learning in the program. The design needs to integrate all learning throughout four-year disciplinary areas and effectively to apply that knowledge into this design project. In addition, this capstone project is an important part of the engineering program assessment. Most engineering programs in the United States have developed their own capstone senior design courses to meet both graduation and the Accreditation Board for Engineering Technology (ABET) requirements. The structural components of the capstone design project depend on each individual program. Some programs had very simple and easy approaches, some programs took a team concept, and some programs requested a lot of components associated with the design.

Although the capstone project is not primarily a demonstration of the student's ability to work problems in a civil engineering specialty, it is a demonstration of the student's ability to organize and complete a project. Specialized technique must be subordinate to the coherence and comprehensiveness resulting from successful self-management. As the pyramid suggests in Figure 1[1], self-management is the foundation of the capstone project. Students must take seriously self-management skill planning on their capstone projects in order to successfully complete the projects. Besides self-management, the capstone project involves technical aspects. Selective disciplinary areas in Civil Engineering areas, such as Structural Engineering, Geotechnical Engineering, Transportation Engineering, Environmental Engineering, or Water Resource Engineering need to be carefully integrated into capstone project. Either too much or too little could cause problem at the end of this process. The report writing and oral presentation, as a part of communication skills, are also important elements associated with capstone project design.

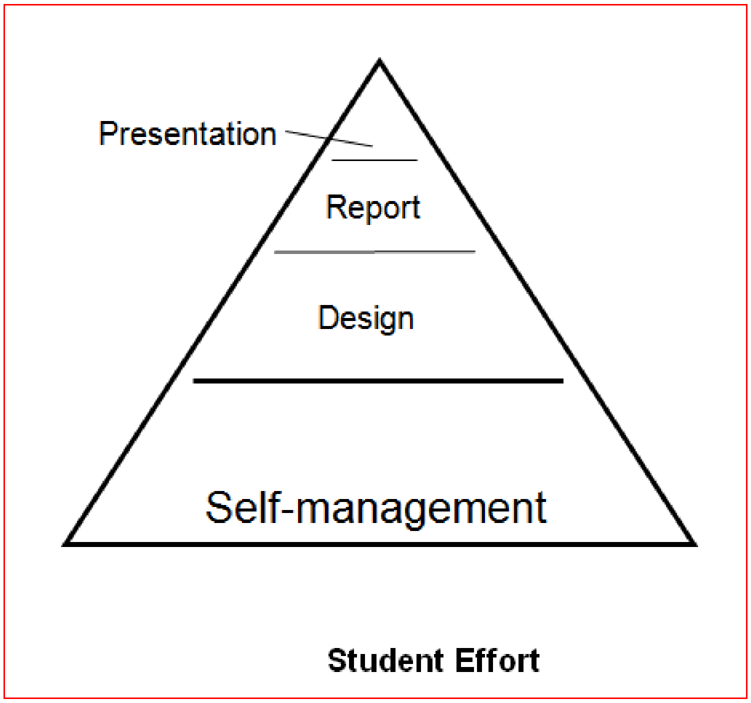

Figure1: Pyramid Structure of Capstone Project

Students in the Department of Civil and Environmental Engineering program at Christian Brothers University are required to take the capstone design courses in their senior year. The project is an interdisciplinary design and an individual project. The design projects were initiated by students and approved by the faculty member(s). At least one professional registered engineer is assigned to each student as industrial practitioner. The objective of this course is to provide students with practical design experience in Civil and Environmental Engineering Areas through a real-world project. These courses also address various management, business/economic, safety, environmental impact, public policy, leadership, and professional issues.

Background of Capstone Design Project

The capstone design projects in CEE Department are CE 431/432 – Senior Design Project I & II, which are offered in the senior year. Each project needs to cover at least two sub-disciplinary areas in Civil and Environmental Engineering. Faculty suggested and/or assigned one industrial professional to each student as its industrial practitioner. Both faculty and practitioners worked with students throughout the entire period. Figure 2 shows the normal consensus relationship among student, faculty, and practitioner[2]. The feasible relationships suggest that student, faculty and practitioner need to work closely in order to secure a better student's performance on their senior design project. The major evaluations and assessments of course outcomes include proposal development, proposal oral presentation, mid-term oral presentation, final presentations, final report, and practitioner evaluation. The major matrices of CE 431/432 of the course outcomes are listed in Table 1. Since these courses span only nine months allowing students to implement and to complete, students constantly expressed several major concerns including: selection of project topics, selection of design components, constrains of schedule, work load, bad-behaved communication, and completion of project. Although the courses have been implemented for a numbers of years, deficiency in this course had been experienced. Several trials had been made before, including a team project, simplification of design contents, and stay-in-class development.

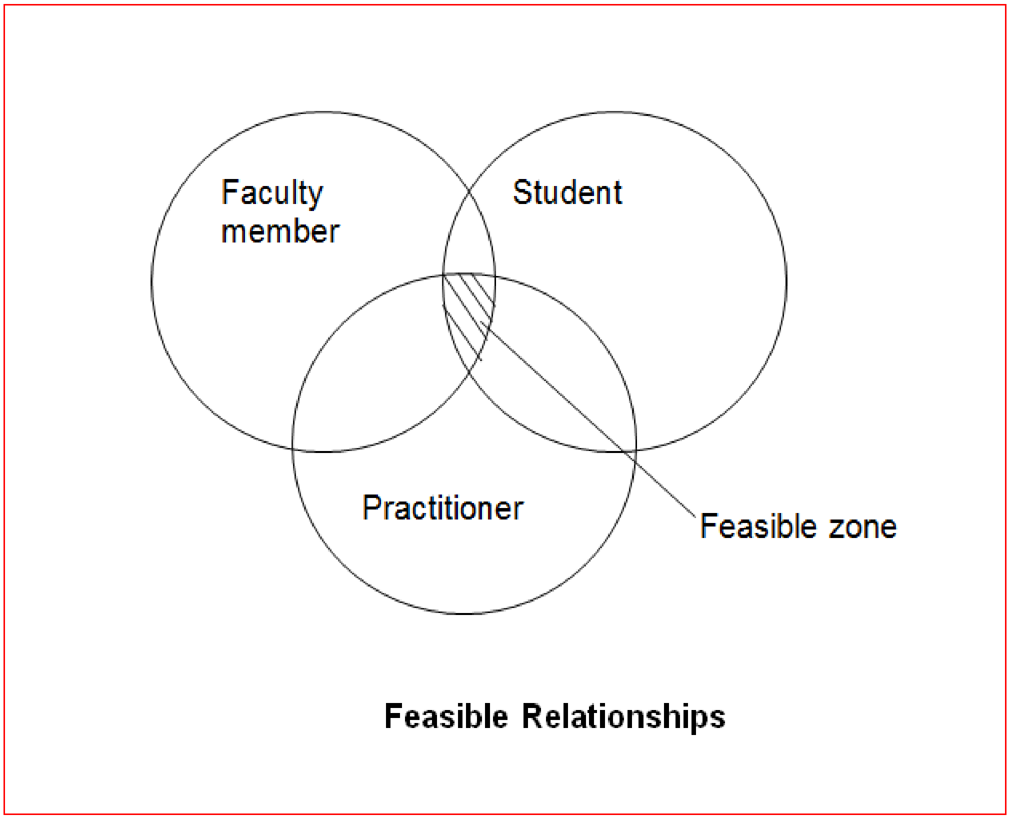

Figure 2: Venn-diagram among Student, Faculty, and Practitioner in CE 431/432

In order to improve the structure this capstone course, one Survey Monkey was sent to practitioners. Five questions were sent to practitioners and board members. The questions were: (1) students need more time to work on the project; (2) students need more planning stage on preparation; (3) students need more guidelines for oral/writing communication; (4) students need more time working with faculty and practitioner; and (5) students need more practical experience from these courses. The survey results of 15 practitioners are listed in Table 2. Almost all practitioners agree on expending the course to three semesters. To assist students in starting earlier, a bridge internship program or summer job was suggested to strengthen student's design skills and assist students in becoming aware of the major components in their capstone project. Several serious discussions among faculty and department's board members were also conducted after the survey results were received. Basically, all members agree with the recommendations from industrial practitioners. A number of actions and plans associated with the results of the survey were taken place.

Table 1: ABET Assessment and Outcomes for CE 431/432

CE 431,432 – SENIOR DESIGN PROJECT

Category (check one)	______	Math/Basic Science
	X	Engineering
	______	General Education
	______	Other
Design (check one)	X	Significant
	______	Some
	______	None
Realistic Constraints (check all that apply)	X	Economic
	X	Environmental
	______	Sustainability
	X	Manufacturability
	X	Ethical
	X	Health & Safety
	X	Social
	______	Political

Relationship to Program Outcomes:

Check all that apply:

X (a) an ability to apply knowledge of mathematics, science, and engineering
X (b) an ability to design and conduct experiments, as well as to analyze and interpret data
X (c) an ability to design a system, component, or process to meet desired needs
X (d) an ability to function on multi-disciplinary teams
X (e) an ability to identify, formulate, and solve engineering problems
X (f) an understanding of professional and ethical responsibility
X (g) an ability to communicate effectively
____ (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
____ (i) a recognition of the need for and an ability to engage in life-long learning
____ (j) a knowledge of contemporary issues
X (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Course Development

One course, CE 331-Junior project, was planned and added into our new graduation paradigm in 2014. The course is a required course offering in the second semester of junior year. Because new Fundamental Engineer Examination (FE) criteria took Thermal Dynamic and Circuit out of the Fundamental Engineering Examination in Civil Engineering area, it is necessary to provide extra Thermal Dynamic and Circuit components in Civil Engineering to our students. In this new CE 331 course, HVAC, insulation, building plumbing systems, building electrical systems, and architectural design were added into its curriculum. In addition, Structural Engineering, Geotechnical Engineering, Transportation Engineering, Environmental Engineering, Water Resource Engineering speakers were invited to the classes. They provide general information of each area to students. Students also need to learn communication and presentation skills. The most important component of this course is to learn self-management skills allowing them to manage the capstone project, to find practitioner, to develop a senior project proposal or an agreement, and to layout design components in their capstone design project. Three manuals: Capstone Project Planning Manual, Oral Presentation Manual, and Writing Report Format Manual were developed. The manuals were posted on school website for students to easily obtain[3].

Table 2: Monkey Survey from Industrial Practitioners

Response	Question 1	Question 2	Question 3	Question 4	Question 5
Strongly Agree	15	14	14	15	14
Somewhat Agree		1	1		1
Neutral					
Somewhat Disagree					
Strongly Disagree					

Since CE 331 is a course for the project planning phase, the most important task of this phase is to provide planning and management skills to our students. The CE Capstone Project Planning Manual was developed for this purpose. This project planning document applies to a situation in which:

- faculty sets the standard of performance for an individual student capstone project
- practitioner assists the student
- student manages and performs the work.

The practitioner is a professional engineer who helps the student during the planning phase. Its task includes:

- select a topic
- evaluate technical decisions
- apply techniques
- judge the accuracy and completeness of work
- possible provide intern to student
- evaluate student works
- assess course outcomes
- provide suggestions and improvement to the course

The peculiar circumstances of a capstone project can be troubling for members of the faculty, the student, and the practitioner. The peculiar circumstances include[4]:

- the student's lack of skill and experience, and a lack of time to work on the project
- the faculty member's lack of time and the need to avoid over-controlling the student
- the practitioner's lack of time to work with the student and lack of authority over the student.

To prevent those peculiar circumstances, the Capstone Project Planning Manual describes in general how the capstone project should be planned. Additional documents are provided to cover the topics of:

- grading
- milestones
- report format
- oral presentation format
- records organization both oral and writing report evaluations
- standard forms.

An agreement or a contract is needed among the faculty member, the student, and the practitioner by the end of CE 331. Coming to an understanding of what the project is about and what quality of work is acceptable is difficult enough for a faculty member and a student. The inclusion of a practitioner in the project further complicates relationships. As the Venn-diagram illustrated in Figure 2, if the undertaking is to be feasible, the faculty member, student, and practitioner should all be satisfied with the plan and progress of the project[5].

The faculty member, student, and practitioner should not come to an agreement immediately or in pairs. Instead, the agreement should evolve through the following steps:

- student advises faculty member of an interest in undertaking a project in a certain civil engineering specialty
- faculty member advises practitioner of student interest
- 1st three-party meeting
    - faculty member, student, and practitioner meet to discuss a topic
    - if the student does not have a specific topic in mind, the faculty member or practitioner may suggest a topic
    - three parties agree on a topic
    - the standards of the entire capstone project are reviewed
- student plans schedule
    - set detailed topic-specific project milestones
    - estimate hours of labor for student and practitioner
    - propose normal frequency, times, and places to meet with practitioner during project
- practitioner reviews student plan
    - the student and practitioner revise plan as needed
- 2nd three-party meeting
    - faculty member reviews schedule, labor estimate, and meeting arrangements
    - three parties finalize agreement

Ideally, a well-planned project will proceed to the satisfaction of all three parties. The scheduled meetings between student and practitioner allow the practitioner to monitor the quantity and quality of the student's work, and the student also gages the degree of support the practitioner provides. The scheduled three-party meetings allow the faculty member to assess the overall success of the student-practitioner partnership and to recommend changes to the undertaking if necessary. The student's project binder is critical to sharing information with the practitioner and faculty member. The agreement can be revised after the student begins work on the project in the

prior summer. If the practitioner cannot devote enough time to help the student, student may request to change or relocate another practitioner. Also, if the student cannot devote enough time to the project, the practitioner may contact faculty advisor and exit the project.
Prior to senior year before CE 431/432 starts it, the framework of capstone project could be developed in the summer. The student should strictly limit the scope of the capstone project. A capstone project is a demonstration of the student's ability to do work that is correct, complete, and timely. Because so many interconnected tasks must be completed, there is simply not time available to take on a large or complex project. Adoption of the U.S. Army Corps of Engineers Six-Step Project Planning Cycle is a suitable approach for capstone project[6,7]. The planning cycle is listed below:

- specify problems and opportunities
- inventory and forecast conditions
- formulate alternative plans
- evaluate effects of alternative plans
- compare alternative plans
- select recommended plan.

During this planning stage, students will adopt this planning cycle to evaluate their capstone project and to develop potential topics for their capstone project.

As an example, limitation of scope is described for a water resources topic[8]. The project scope should be limited in several respects, including:

- geographically--locate the project within a 100 mile radius of the university campus
- areally--limit the area of intense design to 100 acres
- areally--limit the drainage area to 5 square miles if the student is to estimate flows using methods other than USGS regression equations
- linearly--limit strongly linear projects, such as channel job, to a length of one mile
- data volume--limit data to the minimum needed for modeling and quantities
- purposes--limit project purposes to one or two
- clients--limit the clients and stakeholders as much as possible
- specialties--limit the civil engineering specialties required to complete the project
- project life--limit the project life to 50 years, and to only 30 years if possible
- economics--limit the economic considerations used for the comparison of alternatives
- cost--limit the factors that make cost estimation laborious, i.e., numerous materials and numerous parts
- jurisdictionally--limit the county jurisdiction to one county
- fictional boundary conditions--set forth simplifying fictions or assumptions concerning how the actual world relates to the project area.

After the scope has been done, students asked to develop the potential topics for their capstone project. As an example, potential topics for water resources after student discuss with its faculty advisor and practitioner that could be:

- channel stabilization
- flood control channel
- channel floodway or bypass

- river training
- channel meander restoration
- channel grade control structure
- bridge scour
- new bridge, no rise
- embankment dam and spillways
- levee
- pump station
- levee seepage well ditches
- habitat restoration
- urban drainage and storm water detention
- surface water irrigation delivery system
- sanitary sewer stream crossing.

One student rarely has the skills needed to completely design all the potential topics for its capstone project. Therefore, the project features should be organized into three design categories:

- complete
- partial
- nominal

The student should perform a complete design of the features of the project most strongly related to the selected civil engineering specialty. For example, the design of a pump station should include complete hydraulic proportioning of the components water flows through, if the student is focusing on the water resources specialty of civil engineering. The student should perform partial design of the project features that are not hydrological or hydraulic, but are still strongly related to the water resources topic. For example, the design of a pump station should include plausible foundation proportioning for stability of embankments and rigid structural features. Nominal design is performed on features that are not strongly related to water resources or are not normally designed by civil engineers. For example, the design of a pump station should not include the design of electrical wiring, although the need for wiring should be pointed out as a requirement and a rough estimate of the wiring system cost should be included in the total construction cost.

As an example in Table 3, alternatives are listed for a water resources topic[9,10]. Project records relate to the four following alternatives:

- existing conditions (X)
- future without project (F)
- Alternative 1 (A1)
- Alternative 2 (A2).

Exactly four project alternatives are recommended for a water resources project. All water resources projects require a thorough description of existing conditions. All water resources projects require a future without project condition, due to the fact that existing conditions may not persist if a project is not undertaken. In such a case, comparison of an alternative with existing conditions alone does not accurately portray project benefits and costs throughout project life. Even without reason to expect significant change in the project characteristics over the design life, a future without project alternative should be developed to express that expectation formally. The student should develop exactly two project alternatives, because two is the minimum number that allows the student to demonstrate an ability to compare and evaluate alternatives.

Table 3: Alternatives Check-Log

Alternative Sub-Headings	**Alternatives**			
	Existing (X)	Future w/o Project (F)	Alternative 1 (A1)	Alternative 2 (A2)
topography				
hydrology				
hydraulics				
sediment transport				
water quality				
habitat				
geotechnical				
structural				
mechanical & electrical				
drawings				
cost estimate				
economics				
construction				
operation & maintenance				

Project records should be organized in both a computer project directory and on paper in one or more three-ring binders. Using a water resources topic as an example, the blank table below lists the major headings of the project by alternative, with potential sub-headings for each alternative. The student should estimate operating and maintenance costs for each of the four alternatives. Using a water resources topic as an example, costs may include:

- Vegetation
  - lime and fertilizer
  - mowing
  - tree removal
  - spraying to suppress trees
- Access and security
  - gravel replacement
  - rut smoothing
  - fences and gates
  - vandalism
- Sediment
  - channel cleanout
  - scour
  - structural elements

  - riprap
  - reinforced concrete
  - conduits
  - appurtenances
  - Machinery
  - engines
  - electrical motors
  - pumps
  - conduits
  - valves
  - gates
- Electrical
  - utility connection
  - electrical wiring
  - instrumentation.
  -

Finally, the cost analysis should be based on: (1) project life; (2) discount rate; (3) costs, including operating and maintenance costs (O&M); and (4) benefits.

Engineers must not only have strong technical skills on problem solving, but also be technically competent on communication skills to transfer their idea and reasoning to their claims. There is evidence that more and more employers require high standards of college graduates having proper and adequate communication skills. Communication skills become a regular engineering education component. Communication skills in CE 431/432 include several oral presentations, intermedia reports, and a final report. Over the years, communication was among those activities that showed a certain degree of deficiency. Students could not make proper oral presentation, including improper dressing, unsuitable language presentation, inadequate contents, etc. In order to provide the core contents of proper communication, this new capstone curriculum has developed presentation criterion and writing format of reports in Tables 4 and 5. Students have to follow the standards listed in the writing and oral presentation manuals, and implement all items in their presentation and writing reports.

Individual presentations may last only 10 minutes, so the student must cover much in a short time. Students sometimes have difficulty deciding who the audience is, and where fiction and coursework meet. The presentation is not the occasion for the student to show the faculty members that certain mathematical problems were attempted and solved correctly. Instead, the student should imagine the presentation is being given to a city engineer and his staff, or a to comparably trained audience of clients. A city engineer does not want to hear an engineering lecture, and does not want to see detailed calculations, but wants instead to hear about the overall design and its implications. In general, the oral presentation will follow the criterion below:
Department:

- The final presentation for the semester should be made in business dress, which includes coat and tie for men
- Don't act as if the members of the audience are familiar with the project.

Speech:

- Speak slowly and distinctly

- Use good grammar
- Avoid slang
- Avoid a sales pitch
- A simple, direct approach is best.

PowerPoint presentations:

- Proofread slides
- Keep slides plain
- Avoid undignified patterns, garish colors, decorations, and animations
- Avoid long decimal fractions
- Display the same number of decimal places for related values
- Don't present sample calculations.

Table 4: Evaluation Form of an Oral Presentation

CE 315/431/432 CE Design Project Date:______

Evaluation of an Oral Report

Name:_________________ Topic:________________

Factors	5	4	3	2	1	Comments
1) Eye contact /Dress /Timing						
2) Enthusiasm						
3) Knowledge						
4) Organization						
5) Level of detail						
6) Use of visuals						
7) Effective Question & Answer						
8) Creativity in design						
9) Safety addressed						
10) Economics addressed						
11) Environmental Impact addressed						
12) Reasoning						
13) Communication skills						
14) Judgment						
15) Overall presentation						

Rating: 5=Excellent; 4=very good; 3=satisfactory; 2=below average; 1=poor
Comments: There should be suggestions for improvement as well as recognition for excellence.

A single report Writing Format Manual[11] was developed allowing our students to produce a proper and consistent design project report. The report addresses responsibility, professionalism, and quality of the report. Basically, the student is responsible for becoming familiar with the contents of this manual and applying its requirements to the report. In the event that an instruction in this manual appears unclear or conflicts with an approach the student deems necessary, the student shall inform the faculty advisor of the issue in a timely manner and obtain clarification or permission for any deviation adopted. The report shall be of professional quality in organization, format, content, and printing. Reports not meeting the specifications of this manual or otherwise unprofessional are not acceptable. The manual specifies general content.

Table 5: Evaluation Form of a Writing Report

CE 431/432 CE Design Project :Evaluation of a Written Report

Name:_________________ Topic:________________

Factors	5	4	3	2	1	Comments
1) Discussion of problem						
2) Discussion of the constraints						
3) Discussion of alternate designs						
4) Figures & charts referred in the main report						
5) Typical Engineering Report						
Spelling						
Grammar						
Use of subheadings						
6) Figures & drawings done by use of a software						
Enough details						
Attached it properly						
7) Safety issues discussed						
8) Creativity in design						
9) Environmental Impact addressed						
10) Economic considerations						
11) Reasoning						
12) Critical Thinking						
13) Problem Solving						
14) Written Communications						
15) Judgment						
11) Overall Quality						

Rating: 5=Excellent; 4=very good; 3=satisfactory; 2=below average; 1=poor
Comments: There should be suggestions for improvement as well as recognition for excellence.
Suggestions for Improvement/additional comments:

The student is responsible for coordinating with the faculty advisor and practitioner to determine the specific technical content required by the nature of the project and the specialties of civil and environmental engineering the student has elected to focus on in the project.

Conclusion

New design capstone courses were developed for the Department of Civil and Environmental Engineering students at Christian Brothers University. Based on the recommendations from previous industrial practitioners and departmental board members, the entire sequence and structure of the courses have been changed. One CE 331 junior project with a zero-credit hour was added into our curriculum. The course is offered in the second semester of the junior year. It provides supplemental material of FE examination, planning skills, preparation of design materials, knowing their faculty and industrial practitioner. As a result, students will have more time to prepare their capstone project and better management skills to handle the capstone project. CE 331 also provides more time allowing students to interface with faculty/practitioners, to obtain information from Thermal Dynamic and Circuits, to prepare and plan their senior project, and to work with their practitioner prior to their senior year through an internship program. During their senior year, they already either started their senior project, or can jump start their project very quickly.

The guidelines of planning, oral presentation, and report writing report provide them clear and detail information, so that they can follow the format and instruction to complete their project on time. Since the new capstone project courses was implemented in 2014, we have seen the following improvement: (1) well-prepared oral presentations, (2) consistent report writing; (3) high percentage of on-time work; (4) improvement of graduation rates from low 65% to 96%; (5) high industrial practitioner evaluation; and (6) positive student course evaluations.

References

1 ANSI/NISO Z39.18-2005, *Scientific and Technical Reports--Preparation, Presentation, and Preservation*.

2 *The Chicago Manual of Style*, 15th ed. Chicago, Ill.: University of Chicago Press, 2003.

3 Rice, Walter W., *How to Prepare Defense-Related Scientific and Technical Reports--Guidance for Government, Academia, and Industry*, Hoboken, New Jersey: John Wiley Publishing, 2007.

4 U.S. Corps of Engineers, OM 25-1-50, *Correspondence*, Washington, D.C., July, 2001.

5 U.S. Corps of Engineers, OM 25-1-51 *Guidance for Preparation and Processing of USACE Command Publications within HQUSACE*, Washington, D.C., Dec, 2011.

6 U.S. Corps of Engineers, *Guidance for the Preparation of Technical Manuals*, Washington, D.C., May 1996.

7 U.S. Corps of Engineers, ERDC/ITL SR-04-1 *Guide for Preparing Technical Information Reports of the Engineer Research and Development Center*, Vicksburg, Mississippi, July, 2004, Rev. January,2006.

8 U.S. Corps of Engineers, Memphis District, Hydraulics and Hydrology Branch, *Report Style Manual*, Memphis, Tennessee, January, 2004.

9 U.S. Geological Survey, *Standards for Illustrations in Reports of the U.S. Geological Survey, Water Resources Division*, Open-File Report 95-415, Washington, D.C., 1995.

10 U.S. Geological Survey, *Suggestions to Authors of the Reports of the United States Geological Survey*, 7th Ed. Washington, D.C.: U.S. Government Printing Office, 1991.

11 U.S. GPO, *Style Manual*, Washington, D.C.: United States Government Printing Office, 2000.

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