Development of a Civil Engineering Design Course Based On Reflective Action

Aaron S. Bradshaw, Merrimack College
Gary N. McCloskey, O.S.A. Merrimack College
Franklin Miguel, Merrimack College

Abstract

Added to solid technical skills, there are a number of "soft" skills that a civil engineer must possess to be successful in practice. A concept for a course is proposed where students can develop technical and non-technical practice skills using the learning approach of *reflective action* which was first introduced by Donald Schon in the 1980's. Reflective action is demonstrated through a design problem involving the development of a residential housing design aimed at improving the substandard conditions in a poor neighborhood in the Dominican Republic. The course is composed of three parts, with each part representing three active learning components. The first part of the course includes a period of research to prepare participants to conduct field research in the Dominican Republic over spring recess. This preparation is guided by "reflection-on-action," i.e., determining from regulations and prior practice approaches to design that would appear to have application in the local circumstance. In the field research, students are guided in "reflection-in-action" as they apply their preparation to determine on-site applicability as well as the cultural and community implications impacting design. The design will be completed after the students return. It is guided by "reflection-for-action" as they develop a design that meets the local technical and economic realities as well as community and cultural expectations of the people that the design will be meant to serve. The pedagogical approach presented herein may be useful to those developing engineering design courses.

Introduction

Civil engineers must possess, at a minimum, sound analytical skills and a solid understanding of the engineering fundamentals. However, to be an effective civil engineer in practice an individual must also possess a variety of other non-technical or "soft" skills. These include the ability to serve a client, ability to communicate well at various levels, the ability to understand and continually evaluate the problem at hand, the ability to consider the impacts that a solution may have on the community and the environment, and the ability to deal with uncertainties that are prevalent in the natural world. For most students, their first exposure to these aspects of engineering may not be until after graduation when they enter the profession. However, it is also possible to give students "real world" exposure in the classroom if the course can bring in some of these elements.

This paper presents a design for a civil engineering design course where the students apply learned technical skills while fostering their "soft" engineering skills that are critical for success in practice. The course is centered on the concept of *reflective action* to foster development of "soft" engineering skills through guided reflection about action at various stages in the design process on the relation of theories and practices to the specific context for which a design is being developed. According to Killion and Todnem (1991) "Through reflection, we develop context-specific theories that further our own understanding of our work and generate knowledge to inform future practice."[1] In this approach, reflection on the context-specific design also becomes a means for ongoing development of a repertoire of approaches that interconnect the technical and "soft" engineering skills in ways that advance both current and future practice. The course was designed as a directed study course for six students and is currently

being taught by the first author in the current semester (Spring 2008). The learning theory is briefly described and the major elements of the course are discussed in detail in subsequent sections.

Approach of Reflective Action

The approach of reflective action used in this course has its roots in the work of Donald Schon beginning with his work, *The Reflective Practitioner: How Professionals Think in Action* [2] as well as *Educating the Reflective Practitioner* [3]. In his work Schon develops the concept of "reflection-in-action." This approach takes seriously the uncertainties inherent in design practice and make them part of the process by educating designers to question their own assumptions, consider possibilities for reframing approaches as well as to view surprise as an "expected" uncertainty. Reflection-in-action occurs in the application of design principles to a specific situation and involves a "dialogue" that results in a design that better articulates with the circumstance. Implicit in Schon's work are two other reflection phases that are further developed by Killion and Todnem, they are reflection-on-action and reflection-for-action. Reflection-on-action involves reflection in the initial design development prior to reflection-in-action. It involves looking for areas of uncertainty and surprise that a particular context may involve and questioning the assumptions of previous practice with respect to the limitations of application in a particular context. On the other hand, reflection-for-action follows up on reflection-in-action and tries to find in the experience of reflection-in-action practices that can be applied in future circumstances. The course has been designed to give attention to educating for reflection-on-action and reflection-for-action as well as Schon's reflection-in-action.

Student Design Problem

The design problem originated from the third author who is from the Dominican Republic (DR) and currently a civil engineering student at Merrimack College. There is an extreme dichotomy in economic status in the DR where wealthier citizens reside adjacent to others living in extreme poverty. Many of the poor neighborhoods originated from the occupation of land without permission (i.e. squatters). These land invaders or "Invasores" as they are called in the local community staked their claims by building small shacks on parcels of land. These dilapidated houses were built quite literally using any materials that the people could get their hands on. Over time these communities grew as the walls of one house became the walls of the next. One of these neighborhoods, called Luz Consuelo, is shown in the satellite photograph in Figure 1. Notable is the poor condition of the houses as compared to the wealthier surrounding neighborhoods. Figure 2 shows some of the materials that were used to construct their houses including mattresses, metal plates, cement blocks, and wood palettes.

The Dominican Republic lies in a region that is susceptible to numerous natural hazards including hurricanes and earthquakes. Last year, for example, the DR was hit by hurricane Noel resulting in 79 deaths and at least 62,000 homeless [4]. The region also has a history of earthquakes exemplified most recently by a magnitude 6.5 event that occurred on September 22, 2003 [5]. It is clear from the condition of the residential structures in the Luz Consuelo neighborhood (Figure 2) that these structures were not designed to handle these types of environmental conditions. Since the structures are not built to any minimum design standard, such as that would be specific in a building code, they are not protective of public safety.

Figure 1. Photograph showing the Luz Consuelo neighborhood and Movearte School, Santo Domingo, Dominican Republic (Google Earth).

Figure 2. Photograph showing some of the materials that have been used to construct the Luz Consuelo neighborhood Santo Domingo, Dominican Republic.

Given the unsuitable condition of the existing residential structures in the Luz Consuelo neighborhood, the director of the Movearte Technical School which is located just north of Luz Consuelo (Figure 1) is interested in improving the quality of life for these people. Since these people have essentially no monetary resources, future development of replacement housing will require external funding. The Director is in the process of obtaining funds but it is unclear what the future housing will look like. Therefore, the design objective for the students is to design housing that is safe, maintains the integrity of the existing community, and minimizes cost to allow the most effective use of external funds. The course consists of three major phases including research, field research, and design.

Research Phase (Reflection-on-Action)

Typically the first step to any civil engineering project is to collect and understand as much information as possible relating to the problem. The housing design problem has a number of technical research aspects including understanding the environmental loads, identifying commonly used building materials and methods, and investigating the site conditions. Added to the technical considerations, the other aspects that are equally important include an understanding of the Client's needs and the culture that will ultimately interact with the future development. Within the investigation of the technical considerations there will be reflection-on-action examining for areas uncertainties limiting the application of technical understandings in this situation.

Loads from hurricanes and earthquakes will play a significant role on the design. Selection of appropriate wind and seismic design loads will require that the students identify the applicable building codes. If residential building codes are not identified, the students will have to consider alternative codes and their applicability to the problem. In addition to establishing design loads, the students will have to evaluate the risk for flooding in Luz Consuelo during major storm events. A deeper understanding and appreciation for these environmental conditions will be gained through investigation of the historical record of natural disasters in the region and the mechanisms that cause them. Reflection-on-action will involve studying the assumptions of existing building codes to identify the scope of applicability to the reality of the DR.

The building materials and methods will be an important consideration for this project because they must be economical. The availability of these materials is also an important consideration for the community to be able to maintain their homes in the future. The students will have to identify which methods and materials have been used in the past, and their effectiveness, and therefore will utilize reflection-on-action.

Identification of the site topography as well as the subsurface soil and water conditions will be necessary for proper design of the foundation system, site drainage, and septic system. Since a subsurface exploration program is too costly for this project, the students will have to research existing geotechnical data. For example, a number of the buildings were recently constructed at the Movearte Technical School and may provide preliminary design information and a creative avenue for reflection-on-action.

The "Client" in a civil engineering project is usually the individual or entity that pays for the project. In many cases the client may not necessarily have a technical background. Therefore, the client may not actually know what they want, or they may have a preconceived notion of what they want. Any good engineer will work to understand their Client's needs and guide them through the design process. The Client for this project is the Director of the Movearte School as he will be the one responsible for soliciting funds for the redevelopment project. Therefore, the students will have to understand his needs and constraints. Reflection-on-action will involve understanding this project within the larger development of the Movearte School

Ultimately the design must solve the housing problem. Though a solution may be technically doable, if it is has a negative impact on either the community or the culture, then the solution is not really a success. Therefore, the students will have to begin to understand the people of Luz Consuelo to avoid negative cultural impacts. Here reflection-on-action will involve understanding the purposes/aims of the people of Luz Consuelo.

Field Research Phase (Reflection-in-Action)

The on-campus research will undoubtedly result in a number of unanswered questions and data gaps (uncertainties). Therefore, to answer these remaining questions and fill these gaps the students will travel to the Dominican Republic over Spring Recess. The purpose of this trip is to continue to gather the necessary technical information and also to continue to understand their Client's needs and the needs of the community. Here reflection-in-action will be the main process. While designers will work to answer questions and fill gaps, they will also need to be alert to additional (unforeseen) questions and gaps.

Among possible "expected" questions and gaps in technical information include determining the availability and cost of building materials. The designers may also want to identify members of the community who might be willing to help with the construction in addition to construction companies. Since site survey data are not available they will likely have to conduct a site survey to determine property constraints and ground surface elevations.

To better understand the Client's needs and the cultural context of this project, the students will have to conduct personal interviews. This reflection-on-action will get at understandings that cannot be gained technically. Given that the objective is to design a housing solution, it will be critical to understand the potential effects that a design may have on the culture of the Movearte School and the Luz Consuelo community. For example, will the design solution allow the people to continue to function as a community, or could it have implications that may tear them apart?

Design Phase (Reflection-for-Action)

In the design phase, the students will synthesize all the information that they have gathered from the research and field studies to ultimately develop a satisfactory design solution. This will require that they reflect on their technical skills learned in their other course work as well as on their research experiences in the first two sections of the course. In the course work, this will be an introduction to reflection-for-action. In this synthesis the student designers will need to integrate technical and "soft" skill understandings to provide a technically strong and practically feasible design solution.

The students will first develop a number of possible design alternatives that address the technical, client, and cultural aspects. They will then have to rank the alternatives in order to select the "best" design. Unfortunately, the time remaining in the course may preclude completion of a final design. However, even if a final design is not completed, identification of the "best" solution will be a positive outcome. From the perspective of reflection-for-action the "best" solution will include identification of ways to address the concerns and practices that can increase the probability of the "best" solution as a successful solution for the site and communities being served. A final design could always be completed as a follow up course in a successive term. Eventually, through the reflection processes and design findings, it is hoped that any resulting design could be used through reflection-for-action as a model for future development in other Invasores neighborhoods of the Dominican Republic.

Conclusions

This paper presented a civil engineering design course that utilized the learning theory of reflective action. Reflective action evolved from the need to educate design practitioners to deal with uncertainty, and therefore is a well-suited model for educating civil engineers. In this particular course a problem was proposed to students whose solution involved the design of safe and cost-effective housing for a poor neighborhood in the Dominican Republic. Though an international project was described, it is anticipated that the approach could be utilized for any design problem. This pedagogical approach, therefore, may be of interest to those interested in developing engineering design courses.

Acknowledgements

Student travel to the Dominican Republic is funded through a grant provided by the Davis Learning Foundation. The authors would also like to thank Father Manuel Ruiz, Director of the Movearte Technical School, for his help in coordinating this project and for providing room and board for the visiting students.

References

1. Killion, J.P.; Todnem, G.R. (1991). *Educational Leadership*, Vol. 48, Issue 6, 14-16.

2. Schon, D.A. (1983/1991). *The Reflective Practitioner: How Professionals Think in Action*. New York: Basic Books.

3. Schon, D.A. (1987). *Educating the Reflective Practitioner*. San Francisco: Jossey-Bass.

4. dr1.com (2003). "Earthquake Damages at RD$700 Million." http://www.dr1.com. Accessed February 15, 2008.

5. msnbc.com (2007). "Noel Set to Rain on East Coast." http://www.msnbc.msn.com/id/21526342/from/ET/. Accessed February 15, 2008.

Dr. Aaron Bradshaw is currently an Assistant Professor and Interim Chair of the Department of Civil Engineering at Merrimack College. He can be contacted by phone at (978) 837-5325 or by e-mail at aaron.bradshaw@merrimack.edu.

Rev. Gary N. McCloskey, O.S.A. (http://www.merrimack.edu/gmccloskey) is Dean of the College, Chaired Professor of Augustinian Pedagogy and Founding Director of the Saint Augustine Institute for Learning and Teaching at Merrimack College. Beyond Augustinian pedagogy, his teaching and research have included work on instructional technology, curriculum, educational policy, theology, women's studies, popular culture and sustainability.

Mr. Franklin Miguel is currently a civil engineering student at Merrimack College. He can be contacted at miguelf@merrimack.edu.