Sustainable Education for Construction Students

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This study investigated the level of construction students' familiarity and interest regarding sustainability in the built environment, their ability to identify recognizable sustainable rating systems, the important areas of sustainable knowledge for students' employment, and factors affecting students' attitude toward sustainability. To accomplish its main objectives, this study employed a survey research method as a main method of data collection. The survey instrument was developed by authors through in-depth literature review in the areas of sustainability, sustainable construction, sustainable education, and transformation of people's attitude and behavior. The survey instrument was distributed to construction students from sophomores to graduate students at Virginia Tech. The results of descriptive statistics and Analysis of Variance (ANOVA) using SPSS version 16 present the following findings. Construction students perceived that they had a relatively high level of familiarity with sustainable construction and sustainability. Leadership in Energy and Environment Design (LEED) was the most widely recognized sustainable construction rating system by construction students. Construction students also believed that general knowledge of sustainability would help get a job. Finally, several factors of "professors' teaching and research toward sustainability", "work experience related to sustainability", and "courses associated with sustainable development" were perceived to affect students' attitude toward sustainability.

Key Words: Construction Education, Sustainable Construction, Students' Attitude

Introduction

The construction industry including the building sector significantly impacts on our economy, the health of the planet, and the health and quality of life of people (Ahn & Kwon, 2008). Based on the latest U.S. economic census, the construction industry is the largest industry in the United States, employing over 7.19 million people in 732,000 companies and generating revenue over $1.1 trillion in 2005 (Census, 2005). At the same time, the construction industry contributes to environmental issues and problems including global warming, climate change, ozone depletion, soil erosion, desertification, acidification, loss of diversity and agricultural land, land pollution, air pollution, and depletion of natural resources such as forestry, fisheries, oil, coals, minerals, and other goods taken from the earth (Kibert, 2005). One challenge associated with built facilities is their consumption of resources: the operational energy of all buildings in US is 40% of US energy expenditure, and buildings consume 72% of U.S. electricity and 12.2% of all potable water (DOE, 2007 & Roodman & Lenssen, 1995). The industry is also responsible for approximately 25% of the world's wood harvest and 40% of its material and energy flow; it uses 40% of raw materials globally and accounts for 39% of carbon dioxide emissions, 49% of sulfur dioxide emissions, 25% of nitrous oxide emissions, and 10% of particulate matter emissions (DOE, 2007 & Roodman & Lenssen, 1995).With the recognition of these issues and problems, the construction industry has begun to implement the concept of "sustainability" through sustainable construction or green building. The definition of sustainable construction includes the concepts of construction that prevents environmental degradation and utilizes resources efficiently so that the environmental, economic, and social benefits justify the environmental degradation created throughout the buildings life cycle (Guy & Kibert, 1998).

This sustainable construction brings many potential benefits to our society, environment, and economy. The benefits of sustainable construction are summarized in Figure 1. To accomplish the benefits of sustainable construction, the construction industry actively implements sustainable rating systems such as Leadership in Energy and Environmental Design (LEED), the Building Research Establishment Environmental Assessment Method (BREEAM), Green Globes, etc., and invents and employs new sustainable construction materials, technologies, and practices (Ahn & Kwon, 2008 & Langston & Ding, 2003). In addition, public governments at multiple levels have established policies such as Executive Order (EO) 13423, EO 13148, EO 13123, Energy Policy Act of 2005, Energy

Independent Security Act of 2007, etc., and have granted incentives to boost sustainable construction. With the tangible and practical solutions, knowledge of stakeholders and their attitude toward sustainability are more important in order to fully change the construction industry because these attitudes change the paradigm of the construction industry toward sustainability (Cotgrave & Alkhaddar, 2006). Changing stakeholders' attitude toward sustainability and achieving the final goal of sustainability derives in part from formal construction education curricula at the college and university level which integrate the concept of sustainability (Cotgrave & Alkhaddar, 2006, Zhang et al., 2008 & Ahn & Kwon, 2008). Construction programs in the United States have a vital role in sustainable education because they produce construction professionals having knowledge related to sustainable construction. Due to this sustainable knowledge transferring mechanism, it is necessary to include the concept of sustainability as part of construction student education to improve students' attitude toward sustainability. Many academic scholars have studied the importance of sustainable education in several countries including the United Kingdom, Australia, and the United States. However, current studies have not addressed how construction students change their attitude toward sustainability. Thus, this study identified several factors which significantly affected construction students' attitude toward sustainability. To accomplish the research objective, this study employed a survey research method that involved distributing and collecting a survey questionnaire from construction students at Virginia Tech in the United States.
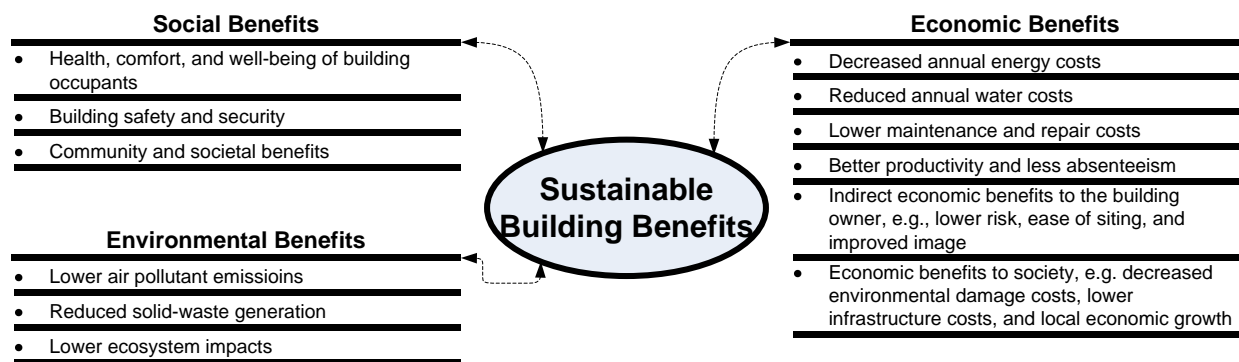

Figure 1: Benefits of sustainable construction (DOE, 2003)

Background of Sustainable Construction

Sustainable construction education for construction students has been studied by several scholars in Australia, the United Kingdom, and United States. Mead (2002) defined the status of sustainable construction in the construction industry and suggested the importance of sustainable construction education in construction programs in the United States. Tinker and Burt (2004) did research about the status of construction courses in construction management programs in the United States. Chau (2007) did research about how sustainability concepts can be incorporated into a civil engineering curriculum. Ahn & Pearce (2007) investigated the expectations of the knowledge of sustainability from construction program graduates by analyzing collected questionnaires from 87 construction companies in the U.S. Hayles, Robson, and Holdsworth (2006) developed a case study about how Royal Melbourne Institute of Technology (RMIT) exposes their undergraduate students to the issues of housing sustainability and affordability. Hayles and Holdsworth (2006) did a case study about how RMIT changed their curriculum for sustainability. Cotgrave and Alkhaddar (2006) undertook research about green curricula within construction programs in the United Kingdom. Haselbach and Fiori (2006) explained the importance of developing an appropriate pedagogy, curricula, and accreditation to achieve sustainable construction in the U.S. Graham (2000) undertook research about teaching and learning environmental literacy for the building professions. In addition, Ahn et al. (2008) developed an undergraduate sustainable construction course for construction students based on systematic course development theory. Zhang et al. (2008) also developed tools and strategies including a course and a textbook for sustainability integration into civil environmental engineering education. Even though many scholars have indicated the importance of sustainable curricula in construction programs, as of a 2004 survey, only a small number of programs including Colorado State University, University of Florida, Texas A&M University, Virginia Polytechnic Institute and State University, Minnesota State University Moorhead, Alfred State College, and

Old Dominion University from among the members of Associated School of Construction offered sustainability-related courses to their students (Tinker & Burt, 2004). Since then, additional leading construction programs at institutions including Arizona State, Purdue, and Georgia Tech have actively incorporated the concept of sustainability into their curricula. Continued growth of interest in sustainability exists across the U.S., although comprehensively identifying newer programs was outside the scope of this research.

In addition to the momentum of sustainable construction education in construction programs, the interest of the construction industry is also a key element of sustainable education because of close interrelation between construction education and construction industry demand for graduates (Cotgrave & Alkhddar, 2006). The construction industry is also truly interested in exposing construction students to the concept of sustainability in colleges and universities (Ahn & Pearce, 2007). According to Ahn & Pearce (2007), 65% of 87 construction firms indicated that they expected construction graduates to have some knowledge of sustainable building. Primarily, the interviewed construction companies expected basic knowledge and concepts of green building, green building rating systems (especially the LEED rating system), green building design process, and other factors (Ahn and Pearce, 2007). Another study conducted by Cotgrave and Alkhaddar (2006) indicated that the most relevant aspects of sustainability to construction students were to develop an understanding of the principles of sustainable construction during the design and construction phase because the graduates generally gained employment with contractors that are involved in these phases of the project life cycle.

In conjunction with a literature review related to sustainable construction education and the industry expectation of sustainable education, in 1976, Ramsey and Rickson identified that the basis for many environmental issues and problems are irresponsible behavior. Additionally, McKeown-Ice and Dendinger (2000) have identified the fact that scientific knowledge and political interventions will not solve environmental problems on their own. Cotgrave & Alkhddar (2006) stated that the main aim of sustainable education was to change students' attitude toward sustainability that should change students' behavior to accomplish the concept of sustainability. Campbell Bradley et al. (1999) stressed the need for trying to change young people's environmental attitudes because young people would be ultimately affected by and would need to provide solutions for environmental problems arising from present actions. Fien (1997) identified that environmental education should play a key role for creating awareness and changing peoples' values, skills, attitude, and behavior. Additionally, Tikka et al. (2000) identified student attitudes toward the environment through comparing students from a variety of educational establishments. The study concluded that although students' backgrounds did affect attitudes, education was the most important factor that contributed to student attitude toward environment. A second study added additional factors such as the sustainable knowledge of educators and sustainable curriculum to influence students' attitude toward sustainability (Woodruff 2006). Because of logical transformation from education to behavior, students' behavior toward sustainability can be changed by changing students' attitude, which is significantly influenced by sustainable education including formal sustainable curricula and the knowledge level of educators.

Objectives of Study

The main objectives of this study were to:

- Identify the level of familiarity of students with the concept of sustainability, especially regarding the construction industry
- Identify the most recognizable sustainable rating systems in the United States to students
- Identify students' perception of the importance of sustainable knowledge for employment
- Measure the significance of factors influencing students' attitude toward sustainability

Methodology

Survey research was the main method used to accomplish the research objectives. The following subsection discusses the survey instrument, the research population, and research procedures.

Survey Instrument

The survey instrument was developed by the authors through reviewing the literature and other survey questions conducted by Cotgrave & Alkha (2006) and Ahn & Pearce (2007). The survey instrument is composed of five sub-categories:

1. Understanding demographic information of each respondent
2. Identifying personal perceptions of sustainability
3. Examining the curriculum for sustainability
4. Recognizing other factors for students' attitude toward sustainability
5. Identifying students' perspective of sustainability in the construction industry.

The individual survey questions were composed of three types: five-point Likert-type scale questions, dichotomous questions, and open-ended questions. The survey instrument was reviewed by a research measurement expert and two academic experts in construction, and pilot tested by 10 Ph.D. students at the Building Construction Department at Virginia Tech. The reliability of questions regarding attitude toward sustainability was measured using the Cronbach alpha. The initial pilot responses received three days later resulted in coefficient of reliability of 0.82. The content of attitude questions was considered reliable and was not revised. Several typographical errors were corrected and several words in the questions were revised to increase clarity. Through these steps, the content validity and reliability of the survey instrument were increased. To protect the rights and ensure the safety of human subjects participating in the research, this study was approved by the university's Institutional Review Board (IRB).

Research Samples and Procedures

This study was a descriptive and correlation study using responses from construction students in the Building Construction Department at Virginia Tech in the United States. The sample size was 254 undergraduate and graduate (M.S.) building construction students excluding first year students because the authors believed that first year students had little or no basis to answer questions regarding the influence of curriculum on their perceptions. The detailed information regarding sample sizes is summarized in Table 1.

Table 1

Research Sample and Response Rate

	Sophomore		Junior		Senior		Masters		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Sample	91	100	68	100	70	100	25	100	254	100
Response	36	40	36	53	30	44	16	64	118	47

The developed and tested survey instrument was encoded using a web survey tool called "Survey Monkey" to facilitate the distribution and collection of the survey questionnaire. After successfully developing the web survey link, the invitation email with the survey link was sent to eligible building construction students with a short invitation letter. The survey link was opened for two weeks to limit the collection period. During the two weeks, the authors sent an additional email to motivate students to participate in the survey. Some faculty also offered extra class credit to motivate students to participate in the survey. In addition, the authors set up the survey program to allow one response per computer which minimizes multiple attempts from students. The total response rate was 47% (n=118). However, there were 4 incomplete responses which were discarded for statistical analysis. The graduate students have a high response rate compared to sophomores from 36% to 64%. Moreover, the response rate increased overall from the lower year to upper year which is clearly represented in Table 1.

Sustainable Curriculum for Samples

The description of sustainable curricula opportunities for students at Virginia Tech is very important for this study because it influences the major outcomes of the study. A professor at the construction program at Virginia Tech has actively conducted research in the areas of sustainable construction and has explicitly taught the concept of

sustainability in one undergraduate course and two graduate courses that are available to all students taking the survey. Table 2 shows the specific courses, target audience, and course description for these three courses.

Table 2

Specific Sustainable Courses at Virginia Tech

Course Name	Level	Description
Construction Principles I	Sophomore	This course focuses primarily on improving your skills and knowledge base in the construction domain in three primary areas: 1) Managing project and team performance 2) Speaking the language of construction 3) Learning how to learn about construction systems You will learn to evaluate construction systems based on their technological, human, ecological, and economic performance over their life cycles. The LEED Green Building Rating System is also covered in this course.
Sustainable Facility Systems	Graduate	Introduction to means, methods, and analytical practices associated with sustainability in the built environment. Best practices for sustainable projects in the areas of planning/development, site design, project management, energy and water conservation and efficiency, green building materials, and indoor environmental quality. Analytical methods include green building assessment tools and methods; Leadership in Energy and Environmental Design (LEED) rating system; economic analysis of green building alternatives; and evaluation for innovation and organizational change.
Sustainable Civil Infrastructure Systems	Graduate	Relevant issues and state of the art technologies for sustainable civil infrastructure systems, including energy generation, water supply/treatment, wastewater systems, solid waste systems, and transportation/mobility systems. Analytical methods include development-scale sustainability assessment tools and methods; green materials performance assessment and evaluation; economic analysis of system alternatives; demand assessment/optimization; and conceptual design approaches for different system types.

Findings & Interpretation

Demographics of participants measured by the study included the status or year of study in university, gender, and the years of experience in the construction industry. The respondent's status in the in the program is shown in Table 1. Eighty seven percent of respondents were male and thirteen percent of respondents were female. Nineteen percent of respondents had no construction work experience, twenty nine percent of respondents had below one year experience, thirty four percent of respondents had one to two years experience and seventeen percent of respondent had over 3 years construction experience.

Familiarity

Familiarity with sustainable construction was measured by composite mean score of two five Likert-type scale questions which were "Are you familiar with sustainability, especially regarding the built environment?" & "Are you familiar with sustainable rating systems in the built environment?" The student responses indicated a level of familiarity with sustainability from 1 (unfamiliar) to 5 (very familiar) with mean of 3.596 and standard deviation of 0.8384. The level of the familiarity of sustainable rating systems had a mean 3.1140 and standard deviation 1.028. An analysis of variance (ANOVA) analysis was run to identify the difference by status or year of study in the university. The test result (Table 3) showed a significant difference of the students' familiarity toward sustainable construction among the status of university level (Sophomores, Juniors, Seniors, and Master Students), having F-value of 17.139 ($p<0.05$). According to multiple comparisons (Table 4) using "Tukey Method", the average score of

the familiarity of sustainable construction between sophomores and juniors, juniors and seniors, and seniors and master students were not significantly different. However, the familiarity with sustainable construction of seniors and master students are significantly greater than sophomores and the familiarity of master students are also significantly greater than juniors. This result clearly shows that the familiarity of sustainable construction is increasing in accordance with academic years in the undergraduate level and the familiarity of master students are higher than undergraduate students.

Table 3

ANOVA Test Result

Familiarity Sustainable Rating

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	23.687	3	7.896	17.139	.000
Within Groups	50.675	110	.461		
Total	74.362	113			

Table 4

Multiple Comparison Result

	Status	N	Subset for alpha = 0.05			
			1	2	3	4
Tukey HSD[a]	2 (Sophomore)	36	2.8333			
	3 (Junior)	35	3.2571	3.2571		
	4 (Senior)	27		3.7037	3.7037	
	5 (Graduate students)	16			4.1562	
	Sig.		.120	.092	.085	

In addition, the result of the other question (1 not, definitely to 5 yes, definitely), "Has your attitude toward sustainability changed since you started your degree program?" supported the analysis because the mean response was 3.88 and the standard deviation was 1.14.

Recognizable sustainable rating systems

Green building rating systems are widely used to measure sustainability in the construction industry. The question, "Which is the most recognizable sustainable rating system?" was a close ended question with 8 rating systems including LEED, Earth Craft, Green Globes, Energy Star, Green Light Programs, NAHB Green Home, and Home Energy Rating System as options. Table 5 shows that LEED is the most widely recognized sustainable rating system among students at this university, Earth Craft, Energy Star, and NAHB Green Home follow, and other rating systems such as Green Globes, Green Lighting Program, and Home Energy Rating System were not recognized.

Table 5

Recognizable Green Building Rating Systems

	Frequency	Percent	Valid Percent	Cumulative Percent
LEED	100	87.7	87.7	87.7
Earth Craft	10	8.8	8.8	96.5
Energy Star	2	1.8	1.8	98.2

NAHB Green Home	2	1.8	1.8	100.0
Total	114	100.0	100.0	

Importance of Sustainable Knowledge for Employment.   This analysis identified the perception of students of the importance of types of sustainable knowledge in the built environment in helping them to get a job after graduation. In addition, the rank of importance of sustainable knowledge was compared to the perspective of contractors solicited in another study conducted by Ahn & Pearce (2007) which identified and ranked the important sustainable knowledge based on a survey of contractors. The result indicated that students and the contractors selected "general knowledge of sustainability" as the most important of sustainable knowledge for their employment. However, students indicated that "sustainable means and methods" were the second most important while the contractors selected "sustainable rating system". Five Likert-type scale questions were asked to students. The detail ranking is listed in Table 6.

Table 6

Importance of Sustainable Knowledge for Students' Employment: Ranking of Topics

	Student Perspective	Industry Perspective
General knowledge of sustainability	1 (3.8)	1
Sustainable rating system	3 (3.5)	2
Sustainable means and methods	2 (3.7)	3
Environmental philosophy	4 (3.3)	4

(   ) mean from the five Likert-type scale

Factors Affecting Students' Attitude toward Sustainability.   Several factors affect students' attitude toward sustainability. These factors are shown in Table 7. The factors were selected by the authors through in-depth literature review. The results of respondents indicated that the most important factor for affecting students' attitude toward sustainability was "professor who is interested in conducting teaching and research". The means of each factor in rank order are shown in Table 7. These results suggest that an important first step to improve students' attitude toward sustainability is to hire a professor who is interested in teaching sustainability and sustainable construction and conducting research in the areas of sustainability. In addition, work experience related to sustainability during students' internship is the second most important factor for affecting students' attitude toward sustainability, and third is the construction industry's interest toward sustainability.

Table 7

Factors Affecting Students' Attitude toward Sustainability

Question Items	Mean	SD
Professor who is interested in conducting teaching and research	4.0632	.98726
Work experience related to sustainability	3.9570	.99906
Interest from the construction industry	3.9158	1.07845
Sustainable construction class	3.7789	.94732
Interdisciplinary classes with the concept of sustainability	3.5474	1.00814
Sustainable facilities in learning classes	2.8229	1.16071

Discussion

Based on the descriptive analysis and ANOVA using SPSS version 16, four conclusions were identified based on findings of the study. Construction students at Virginia Tech perceived that they have a relatively high level of

familiarity with sustainable construction and sustainability. The Building Construction Department at Virginia Tech has incorporated sustainable education into its curricula, including:

- Availability of sustainability-related technical electives beginning in 2004 at the senior and graduate levels
- Hiring a faculty member specializing in sustainability research and education in 2006
- Formal incorporation of sustainability in all four undergraduate years of the core curriculum through guest lectures, modified projects, and readings starting in 2007 (Pearce, 2008)

From the ANOVA test, the familiarity of sustainable construction between sophomores and juniors, juniors and seniors, and seniors and master students were not significantly different. However, the familiarity of sustainable construction of seniors and master students are significantly greater than sophomores and the familiarity of master students are also significantly greater than juniors. This result clearly shows that the familiarity with sustainable construction increases in accordance with academic years in the undergraduate level and the familiarity of master students are higher than undergraduate students.

The most widely recognized sustainable rating system by construction students is LEED, followed by Earth Craft, Energy Star, and NAHB Green Homes. Although none of these rating systems is formally taught as part of the core curriculum at Virginia Tech, students receive guest lectures on LEED at multiple points during the curriculum and are introduced to the rating requirements as part of their senior design-build project. They are also exposed to these tools during summer internships with companies. The results of this survey correspond to the market trend for sustainable construction. Market trends suggest that if a construction program teaches a sustainable rating system as part of an elective course, it may wish to focus on the LEED rating system.

This study also showed that construction students believe that general knowledge of sustainability and sustainable construction may help them get a job after completing a construction program. Students also recognized that sustainable construction means and methods and sustainable rating systems were also very important to enhance job opportunities. This result is similar to contractor's considerations for sustainable construction and sustainability while hiring graduates as determined by Ahn & Pearce (2007). Thus, construction programs may choose to focus on providing general knowledge of sustainable construction and sustainability when beginning to incorporate these concepts into their curricula.

The results related to factors affecting students' attitude toward sustainability clearly emphasize that a professor who is interested in teaching and conducting research in the areas of sustainable construction is the most important factor to influence students' attitude. Thus, this study suggests that the best way to improve students' attitude toward sustainability is to consider hiring a professor whose interest is sustainability and sustainable construction. Since Virginia Tech has already done this as part of its sustainability efforts, respondents to this survey were familiar with the effects of this action. Students at other institutions who do not already have sustainability specialists on staff may respond differently. Thus, additional study is necessary to compare other college construction students' attitude toward sustainability.

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