Evaluation of Life-Long Learning Skill Development in Engineering Curricula

Diane Bondehagen, Environmental Engineering, Florida Gulf Coast University
Claude Villiers, Civil Engineering, Florida Gulf Coast University

Abstract

Life-long learning (LLL) skill development has been long recognized by educators as a valuable attribute that can be an impetus for improved student learning. The Accreditation Board for Engineering and Technology (ABET) criteria (2000) require that engineering programs produce "graduates who pursue life-long learning through continuing education and/or advanced degrees in engineering or related fields". Along with FGCU this new approach has been implemented by different faculty in 3 additional institutions. Results obtained from the data collected including surveys show that the LLL approach in the selected courses engages the students who incorporate more critical thinking and research in their work. Modifications made in the courses to further develop life-long learning skills are assessed in accordance with student perception of their LLL skills.

Keywords

Life-long learning, Engineering education Student Learning, ABET criteria, Curriculum development.

Background

The three participating institutions (Florida Gulf Coast University FGCU, Florida Agricultural and Mechanical University FAMU, and Rowan University RU) included in this study have integrated the specific Accreditation Board for Engineering and Technology (ABET) outcome of Life-long learning (LLL) into their program educational objective (PEO) to meet this ABET criteria1.This PEO states that the program will produce "graduates who pursue life-long learning through continuing education and/or advanced degrees in civil/environmental engineering or related fields" [1].

The Whitaker College of Engineering (WCE) at FGCU University was established in 2005 and offers B.S. degrees in programs in Bioengineering, Environmental engineering, Civil Engineering and Software Engineering. Enrollment is at nearly 900students. At this time, the College offers bachelor degrees and plans to offer master degree programs and a Renewable Energy Engineering program in the future. The teaching mission of of the FGCU WCE is to promote excellence in teaching by incorporating innovation, including integrated lecture lab style methods in all the engineering classes [2].

Rowan University is a public university in New Jersey. The College of Engineering offers four degree programs in Chemical, Civil and Environmental, Electrical and Computer, and

Mechanical Engineering. Today's enrollment is nearly 1200 students. Rowan offers both bachelor and master's degrees, and, like FGCU, is a predominantly a teaching institution.

FAMU University is a historically black university founded in 1887. It awards baccalaureate, master and doctoral degrees by the Commission on Colleges of the Southern Association of Colleges and Schools. The College of Engineering offers bachelor, master and doctoral degrees in majors including Chemical & Biomedical, Civil & Environmental, Electrical & Computer, Industrial & Manufacturing, and Mechanical Engineering.

Introduction

Implementing a life-long learning approach in the classroom requires an examination and reflection upon what researchers have attempted to define as "life-long learning". Laal [3] has defined LLL as "the continuous building of skills and knowledge throughout the life of an individual". This is an inclusive and broad definition, but many more specific definitions have been put forth in the literature. There is no one definition that can be adhered to since the practice of LLL is unique to the each academic environment [4-6]. Given that the problems engineers face are increasingly complex, engineering students should be primed to be "life-long" learners who are continuously learning and adding to their skills set. In the past, the typical engineering education format did not cultivate life-long learning skills and an acquired penchant for life-long learning. Because of this, the challenges to meet ABET criteria are to identify and implement tools and techniques to meet those criteria [7-9].

To specifically address these challenges and concerns, the authors of this paper proposed a new course design that can be used to respond to ABET requirements and criteria[10-13]. As a basis for this approach, a modified version of LLL definition by Smidt and Sursock was used "constant building of student knowledge…throughout his/her engineering career" [14]. Critical thinking, which is the essence of life-long learning[15] should be emphasized in course design since it supports current and future productive research, knowledge synthesis and interdisciplinary communication of knowledge. Accordingly, the authors strived to include student activities that would encourage the development of critical thinking with an emphasis on self-direction. Additional guidelines were used from the literature to design the new course approach[16].

Methods

In order to structure a new approach in the classroom to incorporate and assess LLL, the authors asked the following questions (This approach was implemented and modified over the last 4 years[11,12]. For further evaluation, a survey was administered to engineering graduates this academic year at FGCU (2014-2015).

- What are the students' backgrounds, knowledge, and understanding of LLL?
- When and how should students be exposed to LLL concepts in the curricula?
- Should undergraduate students master their LLL skills while completing their undergraduate degrees or later in their careers, through continuing education and/or advanced degrees in engineering or related fields?
- What are the faculty and administrators' roles in meeting the ABET criteria, especially related to LLL?

- What are the expectations of our graduates from the working industry and/or graduate programs?
- How can faculty measure LLL effectiveness?

The methods used to implement course LLL skills:

1. Identify the student's background on the subject,
2. Design assignments to educate and improve the student's knowledge of contemporary engineering challenges,
3. Cultivate an environment that promotes self-motivation, and
4. Promote a system in which lessons learned from a particular subject or concept can be readily applied across engineering disciplines to facilitate ongoing learning.

Exercises and projects were then developed in all the courses; surveys and rubrics were designed to assess student learning and the potential effectiveness of the new course design. A copy of the survey on student background (step 1) is presented in Table A-1. Once the survey was administered and evaluated, assignments were developed for all classes in accord with steps 2 and 3 of the proposed course structure (design assignments to educate and improve student knowledge of contemporary engineering challenges; to cultivate an environment that promotes self-motivation

Assignments were developed for classes in accord with steps 2 and 3 of the proposed course structure (design assignments to educate and improve the student knowledge of contemporary engineering challenges; cultivate an environment that promotes self-motivation).

<u>Example Life-long learning Assignments</u>**:**

Fluid Mechanics Assignment

- Your group assignment is to identify, research and different innovative technologies that capture (renewable) energy from fluid flow. From your research, identify and list 4-5 articles involving innovative techniques for capturing fluid flow energy

Civil Materials Assignment

- Your group assignment is to identify, research and different innovative technologies that capture(renewable) energy from Civil Engineering materials, more specifically related to hot mix asphalt (HMA). From your research, identify and list 4 to 5 articles involving innovative techniques of capturing the process/production of HMA.

Atmospheric Pollution Assignment

- Prepare a project proposal including at least 5 research articles outlining an innovative remediation technology, best practices approach to major industrial emissions (examples outlined in proposal). Final proposal must include at least 15 peer-reviewed reference

After the assignment was completed, the students were required to report the following (step 4; See Table A-2):

1. Discuss how you think this assignment enhances your knowledge of Life-long learning?
2. How does this assignment change your perspective in terms of Life-long learning?

Analysis and Results

The section below describes the analysis and results obtained from data taken from the following courses and Universities:

Table 1

Engineering Mechanics (Statics and Dynamics)	FGCU 1 yr. data
Civil Engineering (Strength of) Materials	FAMU 1 yr., FGCU 4 yrs., Rowan 1 yr.
Engineering Fluid Mechanics	FGCU 3 yrs.
Engineering Soil Mechanics	FAMU 1 yr.
Atmospheric Pollution	FGCU 2 yrs.

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A. Pre-Evaluation of Student Background on LLL

Throughout 2010- 2015, extensive data (surveys from nearly 400 students) were collected to determine the students' perspectives on life-long learning. The surveys were also designed to determine the effectiveness of the new approach, assess students learning and to rank the performance levels of instructors. A survey was also designed to understand Civil and Environmental Engineering faculty perspectives about life-long learning. Specific questions included "What type of life-long learning approach have you implemented in your classroom?" A copy of the survey is provided in Appendix A (Table A-1).

At the beginning of each semester, a survey was conducted to evaluate student background and understanding of LLL. A copy of the survey is presented in Table A-1. Questions 2 and 5 were in essay format and were evaluated by faculty. The results for the short questions (Q-1, Q-3, and Q-4) in the first survey (Table A-1) are presented in Figures 1, 2, and 3. As perceived and reported by students, the majority had a limited to moderate understanding of life-long learning prior to exposure in courses. It appears that the students at FGCU (as compared to the students from the other participating institutions (RU and FAMU) were more likely to be exposed to life-long learning terminology prior to the introduction of this newly developed concept (see Figure 1). Thirty percent (30%) of students in the FGCU atmospheric pollution course reported they had extensive knowledge of LLL. Also, when the FGCU students matriculate into their programs, they are likely to be exposed to the concept of LLL in a previous engineering course (Fluid Mechanics). As presented in Figure 2, over ninety (90%) of the students in atmospheric pollution were already exposed to LLL from previous courses. This information was also supported by the definition of LLL provided by the students in the essay question responses (see Table A-1). Also, since ABET required the students pursue the life-long learning objective, the officials in the FGCU College of Engineering advised faculty to implement LLL into their courses. As a result, the authors of this paper from FGCU have developed a new course approach to LLL; other faculty at FGCU adapted problems from textbooks. FAMU University also had previously promoted the LLL concept by using various methods to make students and faculty aware of the importance of LLL including posting information in engineering building hallways.

Along with FGCU and FAMU, Rowan University implemented LLL into their program's educational objectives (PEO). However, the students enrolled in the CE materials course responded that they were first introduced to LLL in that course. Some of them even mentioned that their initial exposure to this concept occurred when they first took this survey. And over fifty percent (50%) of the students did not even attempt to define LLL (see Figure 1). Results in CE materials were similar in two consecutive years. It was surprising to discover that students overlooked technology and media as readily available resources to advance their knowledge about the concepts of LLL. On average, only seven percent (7%) reported that they learned about LLL from TV/books/Internet (see Figure 2).

As presented in Figure 2, only eight percent (8%) of the students reported that they were exposed to LLL prior to college. Also, when the students were asked to select the subjects that best prepared them for life-long learning, a small percentage (9% on average) reported non-science high school courses (see Figure 3). Even for high school science courses, fewer than twenty-five percent (25%) of the students reported that these courses prepared them for the concept of LLL. The surveyed responses suggest that in order to produce college graduates that are life-long learners, an effort is required in the high school arena to expose them to LLL concepts as early as possible.

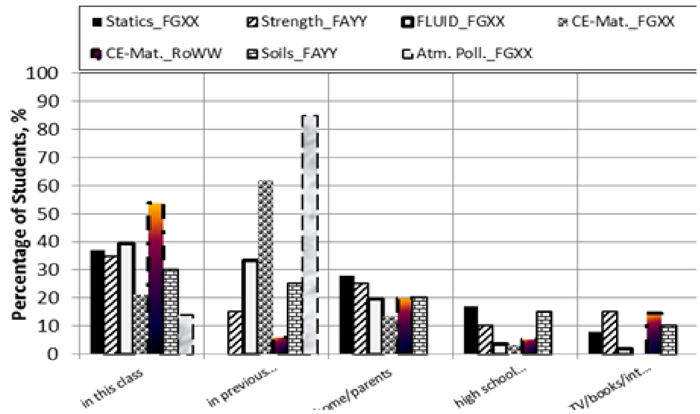

Figure 1. From the following four options, select the one that describe your personal knowledge of the concept of "life-long learning"?
*(FGCU-FGXX;FAYY-FAMU;RoWW-Rowan)

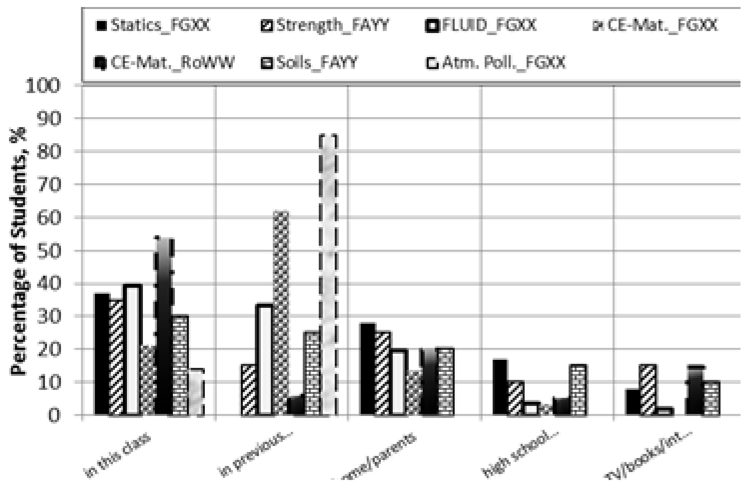

Figure 2. Where have you first been exposed to the concept of life-long learning?

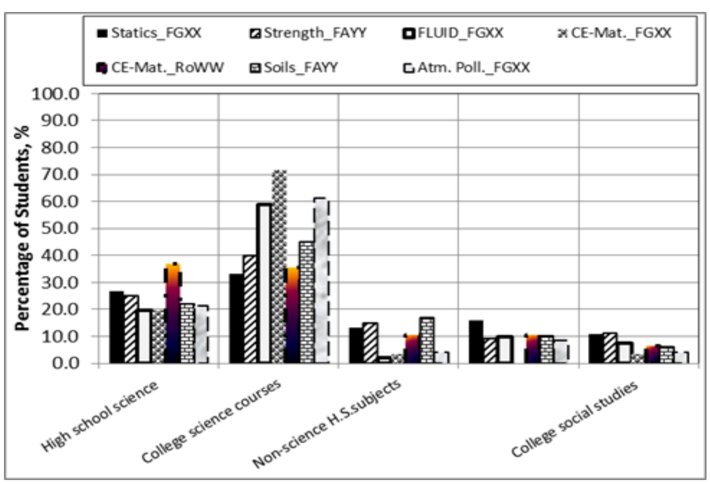

Figure 3. From the list, circle the subjects that best prepared you for life-long learning

B. Post-Evaluation of Students' Background on LLL

In order to establish the environment to encourage and motivate the students towards self-directed learning which the authors recognized as essential to LLL, all the courses were modified to incorporate life-long learning assignments aimed at independent learning. For example, the students in CE materials courses conducted laboratory experiments in four modules on aggregates, concrete, hot mix asphalt and steel. They analyzed data and wrote lab reports for each of the perspective modules. This approach gave the students an opportunity to learn how to conduct professional laboratory tests based on standard specifications and to then write professional reports. To incorporate the LLL approach, the CE materials hot mix asphalt (HMA) modules at FGCU and RU were restructured in the CE materials courses to provide the foundation for self-directed learning. In the first part of the module, the students conducted the lab experiments based on the traditional approach. Then, in the second part, teams of 3 to 4 students identified and researched technologies that promoted sustainability (recycling, energy use). A similar approach was used in the Fluid Mechanics and Air Pollution courses with comparable focus on renewable energy technologies (capturing fluid energy in waves and tides) and emerging technologies in Air Pollution control. Detailed information that supports this concept can be found in previous publications[10-12].

Once the pre-survey was administered and assignments that supported the integration of LLL into the courses were implemented, a final survey was designed and conducted to evaluate the effectiveness of the newly developed approach. The results of this survey are shown in Figures 4, 5, and 6.

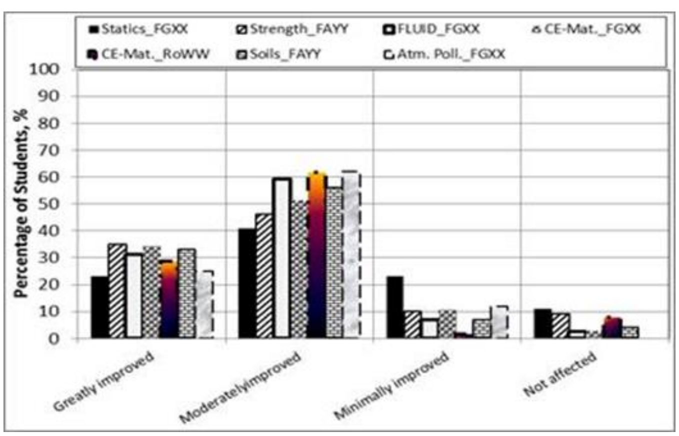

Figure 4. As a result of this life-long learning assignment, my personal knowledge of the concept of "life-long learning" is:

The answers from the students in the final survey demonstrated that the newly developed approach was effective. Inclusive of all classes and institutions, the students reported that their knowledge of LLL had improved greatly or moderately. On average, eighty percent (80%) of

FGCU students, ninety percent (90%) of Rowan students and eighty-five percent (85%) of FAMU students acknowledged that their understanding of LLL had greatly or moderately improved. Additionally, Rowan students presented the lowest percentage (1.6%) to report minimal improvement to the understanding of LLL (see Figure 4). This information is also supported from the comments they provided in the essay questions in the final survey. Students at all universities reported that this approach has helped them to broaden their knowledge about new technologies. “The life-long learning assignment helped me learn a new application of engineering”. “It builds on knowledge and research skills”. The students across the institutions perceived the benefit of the exposure to LLL through the assignments implemented in these courses (Figure 5.). They strongly recommended (nearly 85% on average) that the instructors should continue with this assignment with minor modifications (Figure 6).

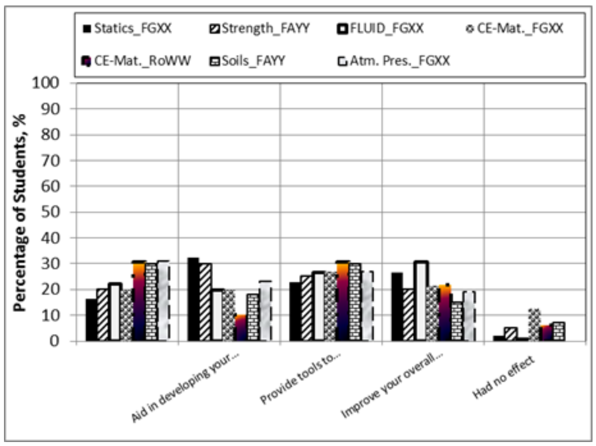

Figure 5. Did the life-long learning assignment: (choose all that apply)

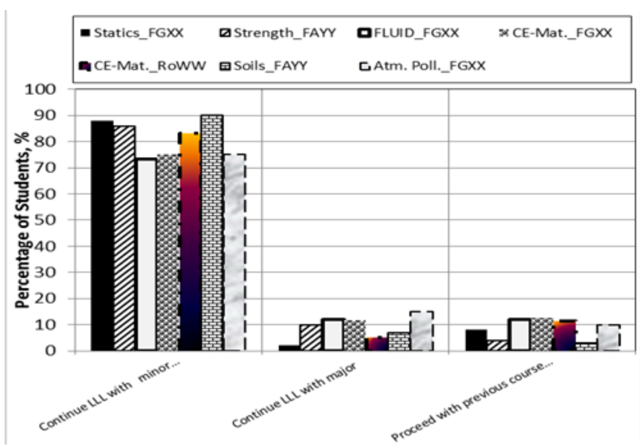

Figure 6. In the future I recommend the instructor.

C. Faculty Perspective to LLL

In an attempt to understand faculty perspective to LLL, a survey was designed and distributed to predominantly civil and environmental instructors at other institutions. A copy of the survey is presented in Appendix Table A-3. Based on the information reported, it was surprising to find that more than seventy-five percent (75%) of the faculty were not aware of the specific ABET criteria, that programs should produce "graduates who pursue life-long learning through continuing education and/or advanced degrees in engineering or related fields". Most of the participants who responded to this survey attended the American Society of Engineering Education (ASEE) conference. Although they were not aware of the ABET mandate in relationship to LLL, over ninety-seven percent (97%) reported implementation of LLL approaches/assignments, either from text books or with their own techniques (see Table 2).

Table 2. Faculty Perspective on life-long learning (percentage)

Category	Questions/Options/factors	Response, %
Discipline	Civil Engineering	71
	Environmental Engineering	9
	Other	20
Institution Size	0 to 10,000	40
	10,000 to 15,000	17
	15,000 to 25,000	23
	Over 25,000	20
College of Engineering Size	0 to 750	27
	750 to 1,000	24
	1,000 to 3,000	21
	3,000to 5,000	15
	Over 5,000	12
Institution Main Focus	Teaching	53
	Research	47
Awareness of the specific ABET criteria related to life-long learning	No	75
	Yes	2
	Somewhat	27
Implementation of life-long learning into particular engineering program	No	6
	Yes	31
	Somewhat	63
Implementation of life-long learning into particular classroom	No	3
	Yes	52
	Somewhat	45
Types of life-long learning approach implemented	Problems from textbooks	7
	Your own designed exercises	61
	Adapted life-long learning approaches/exercises from the literature	7
	Other	25

As a follow-up to previous years' results, a survey of faculty was implemented to determine life-long learning exercises implemented and whether an awareness of this approach had affected course make-up. Preliminary results show a significant percentage of engineering faculty are modifying their courses to include life-long learning exercises.

Table 3. Faculty Perspective on life-long learning (percentage)

Category	Questions/Options/factors	Response, %
Discipline	Civil Engineering	
	Environmental Engineering	Data being collected
	Other	
Institution Size	0 to 10,000	
	10,000 to 15,000	
	15,000 to 25,000	Data being collected
	Over 25,000	
College of Engineering Size	0 to 750	
	750 to 1,000	
	1,000 to 3,000	Data being collected
	3,000to 5,000	
	Over 5,000	
Institution Main Focus	Teaching	Data being collected
	Research	
Effectiveness of life-long learning classroom approach	Very effective	Data being collected
	Minimal to moderate effectiveness	
	Not signifiant	
Ease of implementation of life-long learning into particular engineering program	Easy to implement	Data being collected
	Moderately difficult to implement	
	Difficult	
Types of life-long learning approach implemented	Problems from textbooks	Data being collected
	Your own designed exercises	Data being collected
	Adapted life-long learning approaches/exercises from the	Data being collected
	Other	Data being collected

To further assess faculty activity, a statistical analysis was performed to determine if factors including discipline, institution/engineering program, and teaching/research focus, may affect the type of life-long approach(es) implemented by the faculty in their classroom. The authors tested the null hypothesis that the the type of life-long approach implemented by the faculty are not affected by any of the factors. Low P-values (less than 0.01) imply that the data do not support the null hypothesis. The results are presented in Table 4. Based on the information presented in the table, no significant difference was found between the types of LLL methods and the selected factors.

Table 4. Results of ANOVA for effect of different semesters on student report grades

	P-value	Significant at 95%
Life-long learning approach * discipline	0.539	No
Life-long learning approach * Institution Population	0.870	No
Life-long learning approach * Engineering Population	0.801	No
Life-long learning approach * Teaching/Research	0.612	No
Life-long learning approach * Aware of ABET LLL	0.829	No
Life-long learning approach * Engineering Program LLL	0.591	No
Life-long learning approach * Faculty LLL implementation	0.117	No

D. Perspective on life-long learning after graduation

A survey was devised to assess student perspectives on life-long learning who are now in the workplace or graduate programs. Questions posed are listed below.

- Did the life-long learning approach in your course impact your critical thinking and research skills in the workplace or graduate program?
- Did the life-long learning approach in your coursework improve your overall engineering knowledge?
- Did this approach help you develop what you consider as necessary engineering skills?
- Did this approach provide tools, aid in your understanding of local needs and challenges of your current work?

Initial student response is positive to the curricula assignment modification. Comments received indicate an appreciation of development of research skills as well as employer feedback on overall engineering knowledge and skills. More analysis will be done with a future increased number of student responses.

Analysis and Results

The life-long learning approach to all the courses appears effective in engaging students; they respond well to working with real life challenges. Modifications made in coursework to implement the concept of life-long learning (LLL) results in significant improvement in the students' perspective and understanding of LLL. Innovation continues in the implementation of LLL exercises in the classroom based on instructor experience and observations of results; it is interesting that seventy-five percent (75%) of the faculty who completed the survey were not aware of the specific ABET criteria that engineering programs should produce "graduates who pursue life-long learning through continuing education and/or advanced degrees in engineering or related fields”. Nevertheless, over ninety-seven percent (97%) of them have implemented some level of LLL approach in their courses.

Additional data will continue to be collected from faculty and from student graduates to aid an assessment of the effectiveness of the LLL approach and to incorporate innovative approaches to life-long skill development. Also, because of the success of these life-long learning exercises, more self-learning exercises will be incorporated other courses across the curricula in order to encourage critical thinking and improved learning outcomes .

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Diane Bondehagen, Ph.D

Diane Bondehagen is an Assistant Professor of Environmental Engineering in the Department of Environmental and Civil Engineering, U.A. Whitaker School of Engineering, Florida Gulf Coast University. She received a B.S. in Mechanical Engineering from the University of Wisconsin, Madison, in 1983, an M.S. in Civil and Environmental Engineering from Florida International University in 1999 and a Ph.D. in Environmental Engineering Sciences from the University of Florida in 2005. Her current research interests are include Engineering Education and contaminant transport/remediation.

Claude Villiers, Ph.D.

Dr. Villiers is an Associate Professor in the U.A. Whitaker College of Engineering (WCOE) at Florida Gulf Coast University. He received his Ph.D. in Civil Engineering with a concentration in Materials and Construction from the University of Florida in 2004. Dr. Villiers' areas of principal research interest are Civil Engineering Materials and Asphalt, Transportation, Specifications and Construction Variability of Pavement Materials, Quality Control/Quality Assurance, Pavement Management and Rehabilitation, and Life-long learning application in engineering.

Appendix A

Table A-1. Survey questions used to evaluate the student background and understanding of life-long learning

Q-1	From the following four options, select the one that describe your personal knowledge of the concept of "life-long learning"? A. Extensive B. Moderate C. Limited D. No idea
Q-2	From your point of view please define life-long learning in the space below.
Q-3	Where have you first exposed to the concept of life-long learning? A. In this class B. In previous engineering classes C. Home/parents D. High school teacher E. TV/Books/Internet
Q-4	From the list of subjects below, circle the subjects that best prepared you for life-long learning? A. High school science (chemistry, physics, biology etc.) B. College science courses C. Non-science high school subjects (English, History, Art etc.) D. College humanities courses (Music, Art, Philosophy etc.) E. College social studies (Sociology, political science, anthropology etc.)
Q-5	How do you think this course might prepare you for your own life-long learning? (Use the space below)

Table A-2. Survey questions used to assess student percepa-tions on life-long learning at course end

Q-1	As a result of this life-long learning assignment, my personal knowledge of the concept of "life-long learning" is: A. Greatly improved B. Moderately improved C. Minimally improved D. Not affected
Q-2	Did the life-long learning assignment (choose all that apply). A. Engage you in life-long learning? B. Aid in developing your engineering skills? C. Provide tools to understand local needs/challenges of SW Florida (better evaluate new technologies for local application D. Improve your overall engineering knowledge? E. Had no effect
Q-3	Rate your individual effort in fulfilling your team responsibilities in completing the life-long learning assignment. A. Excellent: Consistently went above and beyond – tutored teammates, carried more than his/her fair share of the load. B. Very Good: Consistently did what he/she was supposed to do, very well prepared and cooperative. C. Satisfactory: Usually did what he/she was supposed to do, acceptably prepared and cooperative. D. Ordinary: Often did what he/she was supposed to do, minimally prepared and cooperative. E. Marginal: Sometimes failed to show up or complete assignments, rarely prepared. F. Unsatisfactory: Consistently failed to show up or complete assignments, unprepared. G. No Show: No participation at all
Q-4	In the future I recommend the instructor: A. Continue with this life-long learning assignment while implementing minor modifications B. Continue with this life-long learning assignment while implementing major modifications C. Proceed with previous year's course assignment of life-long learning textbook problems.

Table A-3 Questionaire- Perspective of Faculty on Life-long Learning

1. What is your discipline?
☐Civil Engineering ☐Environmental ☐Other: ____________

2. Estimate your institution student population.
☐0,000 to 10,000 ☐10,000 to 15,000 ☐15,000 to 25,000 ☐over 25,000

3. Estimate your College of Engineering student population.
☐0 to 750 ☐750 to 1,500 ☐1,500 to 3,000 ☐3,000 to 5,000 ☐over 5,000

4. Is your institution predominantly?
☐Teaching ☐Research

5. Are you aware of the specific ABET criteria that engineering program will produce "graduates who pursue life-long learning through continuing education and/or advanced degrees in engineering or related fields" (Please select only one)?
☐No ☐Yes ☐Somewhat

6. Has life-long learning been implemented into your engineering program?
☐No ☐Yes ☐Somewhat

7. Have you implemented lifelong learning into your classroom?
☐No ☐Yes ☐Somewhat

8. What type of life-long learning approach (es) have you implemented into your classroom? — Approximate Percentage
   1. Problems from textbooks — 1 ☐
   2. Your own designed exercises — 2 ☐
   3. Adapted life-long learning approaches/exercises from the literature — 3 ☐
   4. Other ____________ — 4 ☐

9. Comments or additional information (Use separate sheet if needed). ____________