Paper ID #36534

Does In-Class Problem-Solving Approach Help Students Learn and Improve their Performance? A Case Study

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Does In-Class Problem-Solving Approach Help Students Learn and Improve their Performance? A Case Study

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Abstract

In-class problem-solving in the field of science and engineering is one of the active learning approaches to engaging students in activities in face-to-face class settings and online environments. Engineering and science students are trained to design and construct solutions to problems in the real world. This paper presents the perceptions and attitudes of students who participated in in-class problem-solving activities in an environmental engineering course for four semesters. One of the courses from the Civil and Environmental Engineering curriculum, *Introduction to Environmental Engineering* was used to verify whether in-class problem-solving activities help students learn and improve their overall course grades. Problem-solving in the class as a part of course delivery was conducted on each topic of the course. At the end of the semester, a survey with three Likert-scale questions for three perception scenarios was conducted, and the data was analyzed to determine the students' perceptions and attitudes about the activities in terms of their learning experience and performance. The final grades were also analyzed statistically and compared with previous similar semesters' final grades to predict the effect of in-class problem-solving activities. Negative to flat correlations were observed among the perception scenarios (tests reflected with materials covered as well as course content and course outline) and weighted average GPA, whereas a positive correlation was observed between in-class problem-solving and weighted average GPA. Although statistical differences were not significant, students' perceptions and attitudes were positive and indicated the effectiveness of in-class problem-solving activities in improving the overall performance.

Keywords: Perception, attitude, in-class problem-solving, performance improvement, engineering education

Introduction

In-class problem-solving, other way it can be designated as active learning is one of the learning strategies used in different settings of course offerings in engineering and science disciplines. In-class problem-solving activities engage and challenge students using real-life and imaginary situations where students engage in such higher-order thinking tasks as analysis, synthesis, and evaluation[1]. Active learning is a broad concept used to refer to educational approaches designed to make students participate rather than passively listen. According to Felder and Brent "anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes"[2]. Active learning can also be defined as any instructional method that engages students in the learning process[3]. In short, active learning requires students to do meaningful learning activities and think about what they are doing[4]. In addition, active learning pedagogical activities in both Traditional Classrooms and Active Learning Classrooms influence students' satisfaction with their learning processes positively[5]. An investigation of the long-term effects of active learning methods on student retention in an introductory engineering statistics class was carried out in two classes of students: one was with traditional lecture-based learning, and the other class was with group projects and cooperative learning-based methods[6]. The findings suggest that active learning can help to increase retention for students with average or below average scores[6]. A study by Shaharanee et al.[7] used the Technology Acceptance Model (TAM) to measure the effectiveness of the learning activities 100 valid responses from the students indicated that most of the students were satisfied with the Google Classroom's tool that were introduced in the class. Results of data analyzed showed that all ratios are above averages, in particular, comparative performance was good in the areas of ease of access, perceived usefulness, communication and interaction, instruction delivery and students' satisfaction towards the Google Classroom's active learning activities[7]. TAM was developed by Davis[8] to explain computer-usage behavior. There are two critical determinants of the actual system used: perceived ease of use (PEOU) and perceived usefulness (PU). A study by Berlanga and Garcia-Penalvo[9] used active methodologies in flipped classrooms. It concluded that due to the diversity of students' knowledge and expertise, dialogic interactions between them foster a deep concept understanding, linkage and contribution to collective intelligence establishment between students and teachers. Another study[10] meta-analyzed 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate STEM courses under traditional lecturing versus active learning. The effect sizes indicated that, on average, student performance on examinations and concept inventories increased by 0.47 SDs under active learning (n = 158 studies), and that the odds ratio for failing was 1.95 under traditional lecturing (n = 67 studies). These results also indicated that average examination scores improved by about 6% in active learning sections and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. Problem-based learning presents the most difficult method to analyze because it includes a variety of practices and lacks a dominant core element to facilitate analysis and rather, different implementations of PBL emphasize different elements, some more effective for promoting academic achievement than others[3]. Faculty adopting PBL are unlikely to see improvements in student test scores but are likely to positively influence student attitudes and study habits. Studies also suggest that students will retain information longer and perhaps develop enhanced critical thinking and problem-solving skills, especially if PBL is coupled with explicit instruction in these skills[3]. PBL as suggested by a study is more nurturing and enjoyable and PBL graduates perform as well, sometimes better than traditional graduates[11]. Shorter lectures punctuated with activities to engage students in the learning process can increase student understanding, critical thinking, and overall learning[12].

Student resistance to active learning, including reasons for this opposition and strategies to prevent or respond to it was explored in a study[12]. This study suggested to recognize the factors that lead to students' resistance to active learning is important to mitigating these barriers to learning and equally critical to mitigating student resistance is the promotion of student resilience. This study also suggested structuring classrooms to promote resilience includes community building, structured activities, and policies that recognize student diversity, and the complexity of learning processes.

This study was designed to answer a question: What are the students' perceptions and attitudes about the in-class problem-solving for civil/environmental engineering type of courses and the effect of in-class problem-solving on overall performance? A course (CE 3702 - Introduction to Environmental Engineering) from the civil and environmental engineering program curriculum was used in fall 2021, spring 2022, summer 2022, and fall 2022 semesters to implement this study. An objective was formulated to understand the students' perceptions and attitudes about in-class problem-solving and their overall performance in the course. The objective was accomplished via online and face-to-face anonymous surveys and statistical analyses of the survey data as well as the final course grades. The primary goal of this study was to understand the overall effect of in-class problem-solving on students' perceptions and attitudes as well as on performance improvement.

Study Methodology

The in-class problem-solving that was the practice of multiple problem solving, covering the topic in a group of 2 or 3 after each topic of the course as a study conducted by the author[13] found that a group of 3 or 4 is optimum to perform better in a PBL course. So, the courses were set up for in-class problem-solving assigning problems similar to the class materials covered in a topic instead of PBL. The instructors covered the class materials by lecturing and solving problems on the board for an hour or so and students were asked to solve similar types of problems for 15 to 20 minutes for a typical 75-minute lecture class. During the in-class problem-solving session, the instructor moved around to see each group's progress and help as necessary to keep the groups on track. Although students were allowed to work in groups, finally, they had to submit the solutions individually for grades. The individual submissions were graded and used to assign students 10% bonus points for fall 2021 and spring 2022 and 10% mandatory points for summer 2022 and fall 2022 in their final grades. All the sections used in this study were taught either in hybrid or F2F. Repeated in-class problem-solving for each topic of the course was the only option used. This study option was a part of the syllabus, and the instructor explained, on the first day of the class, how these activities would be conducted and used for grades. The instructor also informed the students about the survey to be conducted at the end of the semester. Since in-class problem-solving was for the bonus points only fall 2021 and spring 2022, there were no modifications on the number of practice problems and types of homework. However, the number of practice problems and types of homework were reduced for summer and fall 2022 to balance out the student anxiety as mandatory points were assigned for these two semesters.

The assessment instruments used to conduct this study were online or F2F surveys as preferred by the instructor and the final class grades. To understand the effect of in-class problem-solving on the perceptions and attitudes of students, surveys were conducted at the end of the semester with three questions to compare the students' learning experiences. The survey questions are presented in Figure 1. The first two questions were asked to understand the students' perceptions and attitudes about the course content and alignment. The third question introduced the in-class problem-solving and its effect.

Q.1. Did tests reflect the material covered in the class?
  a. Excellent (5)
  b. Above Average (4)
  c. Average (3)
  d. Below Average (2)
  e. Very Poor (1)

Q.2. Is there a good agreement between the course outline and the course content?
  a. Excellent (5)
  b. Above Average (4)
  c. Average (3)
  d. Below Average (2)
  e. Very Poor (1)

Q.3. Do you think that in-class problem-solving helped you do better in the course and learn the course materials?
  a. Excellent (5)
  b. Above Average (4)
  c. Average (3)
  d. Below Average (2)
  e. Very Poor (1)

Figure 1: Survey questionnaire for the study

The data collected through the surveys were analyzed to understand the students' perceptions and attitudes about the course content and alignment, in-class problem-solving, and the degree of learning. The data was collected for four semesters, fall 2021, spring 2022, summer 2022, and fall 2022. Table 1 shows the statistics of enrollment, number responded, and the percentage responded in each semester.

Table 1: Enrollment, number responded, and the percent responded in each semester

Semester	**Enrollment**	**Number responded**	**% Responded**	**Scenario in grade**
Fall 2021	44	29	66	10% bonus points
Spring 2022	23	10	43	ditto
Summer 2022	18	18	100	10% mandatory points
Fall 2022	16	12	75	ditto
Total	**101**	**69**	**68**	**---**

Of a total of 101 students enrolled in the class for the four semesters, 69 (68%) participated and responded to the survey questions and 32 students (about 32%) did not participate or respond in the study. Percent responded for fall 2021 and spring 2022 were low because the survey was conducted online, and the in-class problem-solving exercises were not mandatory. The analysis of data was performed with simple statistics using Excel for Goodness-of-fit tests such as ANOVA, χ^2-tests, student t-Tests, and F-Tests, as necessary. The results of the data analysis are illustrated in the following section. Please note that some of the responses to questions/options/choices, as seen in the Tables and Figures, might not sum up to 100% as few students did not respond to all questions or selected all options or preferences.

Results and Discussions

Based on the responses to Q.1 (Figure 2), the participants liked tests reflecting the material covered in the class. Overall, about 45% of the participants chose “5”, 34% chose “4” scales, 17% chose “3” scale, 3% chose “2” scale, and 0% chose “1” scale fall 2021 with a weighted average score of 4.21; about 10% of the participants chose “5”, 50% chose “4” scales, 40% chose “3”, and 0% chose both “2”, and “1” scales for spring 2022 with a weighted average score of 3.70; about 33% of the participants chose “5”, 44% chose “4” scales, 22% chose “3”, and 0% chose both “2”, and “1” scales for summer 2022 with a weighted average score of 4.11; and about 33% of the participants chose “5”, 50% chose “4” scales, 17% chose “3”, and 0% chose both “2”, and “1” scales for fall 2022 with a weighted average score of 4.17. The weighted average score was estimated using the % of student responses as weight. The example weighted average score for fall 2021 = (1x0%+2x3%+3x17%+4x34%+5x45%)/(0%+3%+17%+34%+45%) = 4.21.

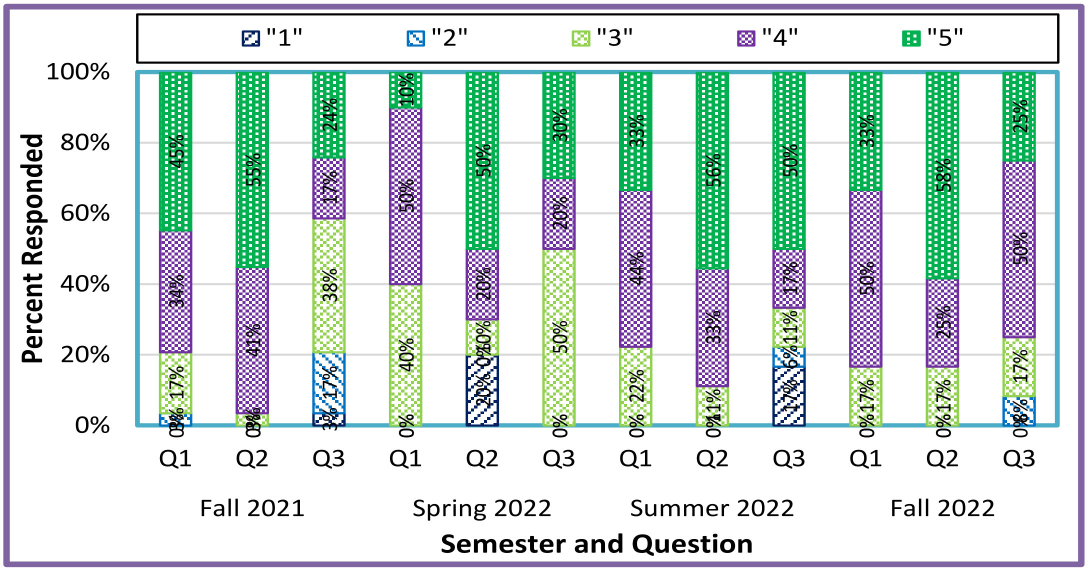

Figure 2: Distributions of responses to survey questions by semester

Somewhat similar responses were observed for Q.2 for all semesters and the weighted average scores were close (4.52 for fall 2021, 3.80 for spring, 4.44 for summer 2022, and 3.87 for fall 2022). Based on the responses to Q.3 (Figure 2), whether in-class problem-solving helped the participants do better in the course and learning the course materials, overall, about 24% of the participants chose “5”, 17% chose “4” scales, 38% chose “3” scale, 17% chose “2” scale, and 3% chose “1” scale for fall 2021 with a weighted average score of 3.41; about 30% of the participants chose “5”, 20% chose “4” scales, 50% chose “3”, and 0% chose both “2”, and “1” scales for spring 2022 with a weighted average score of 3.80; about 50% of the participants chose “5”, 17% chose “4” scales, 11% chose “3”, and 7% chose both “2”, and “1” scales for summer 2022 with a weighted average score of 3.78; and about 58% of the participants chose “5”, 25% chose “4” scales, 17% chose “3”, and 0% chose both “2”, and “1” scales for fall 2022 with a weighted average score of 4.42. The weighted average scores varied widely for Q.3 and remained less than 4.0.

An assessment was performed based on the final grades to compare the effectiveness of the in-class problem-solving for fall 2021, spring, summer and fall 2022 (with in-class problem-solving - ICPS) and fall 2018, spring, summer and fall 2019 (without in-class problem-solving) as shown in Table 2 and Table 4. No comparisons were made with any semesters of 2020 and spring 2021 as these semesters were affected by COVID-19 interventions. The weighted average grades were estimated based on the number of A, B, C, D, and F with an assigned score of A=4.0, B=3.0, C=2.0, D=1.0, and F=0. For example, weighted average GPA for Fall 2021 = (10x4+23x3+9x2+0x1+2x0)/(10+23+9+0+2) = 2.8863 ≈ 2.89. Expected GPA is estimated as the total GPA for all semesters divided by the number of semesters (2.89+2.86)/2 = 2.87.

Table 2: Weighted average GPA with and without active learning options

Semester (w/ICPS)	**Weighted Average GPA**		**Semester (w/o ICPS)**
	With in-class problem-solving (w/ICPS)	**Without in-class problem-solving (w/o ICPS)**	
Fall 2021	2.89	2.88	Fall 2018
Spring 2022	2.43	2.65	Spring 2019
Summer 2022	2.94	2.85	Summer 2019
Fall 2022	3.06	2.86	Fall 2019

Based on Table 2 data, a single factor ANOVA was performed for the two groups (w/ICPS and w/o ICPS), and the results are presented in Table 3. Since $F<F_{critical}$, the null hypothesis cannot be rejected. Thus, the populations of the two options are statistically equal.

Table 3: ANOVA analysis for Table 2 data

Group	**Sum**	**Count**	**Average**	**Variance**	***Source***	***SS***	***DF***	***MS***	***F***	***p-value***	F_{crit}
w/ICPS	11.84	4	2.959	0.0055	*Between group*	*0.0463*	*1*	*0.0463*	*5.5155*	*0.0572*	*5.9874*
w/o ICPS	11.23	4	2.807	0.0113	*Within group*	*0.0503*	*6*	*0.0084*	---	---	---

Based on the data in Table 4, chi-square tests were performed, and the tests statistics are shown in the same Table. For fall 2021 and fall 2018, a *p*-value of ***0.9962*** was obtained which is greater than both 0.05 (α = 5%) and 0.01 (α = 1%) and a χ^2-value of ***0.0000*** was obtained. For a degree of freedom (DF) of 1, the critical values for χ^2 are 3.84 (for α = 5%) and 6.63 (for α = 1%). The *p*-value is greater than both 0.05 (α = 5%) and 0.01 (α = 1%) and χ^2-value is less than critical values for both α = 5% and α = 1%. Therefore, null hypothesis cannot be rejected. This means no significant differences could be observed in two learning options. The same conclusions can be drawn for the pairs of spring 2022 and 2019, summer 2022 and 2019, and fall 2022 and 2019 as shown in Table 4.

Table 4: Assessment based on final grades and weighted average GPA using Chi-square Goodness-of-fit test

Course	**A=4**	**B=3**	**C=2**	**D=1**	**F=0**	**Total**	**Weighted Average GPA**	**Expected GPA**	***p*-value**	**DF**	**χ^2-value**
Fall2021	10	23	9	0	2	**44**	2.89	2.88	0.9962	1	**0.0000**
Fall2018	8	14	9	0	1	**32**	2.88	2.88			
Spring 2022	5	9	4	1	4	**23**	2.43	2.54	0.9244	1	**0.0090**
Spring 2019	7	17	8	3	2	**37**	2.65	2.54			
Summer 2022	5	7	6	0	0	**18**	2.94	2.90	0.9862	1	**0.0016**
Summer 2019	7	9	4	1	0	**33**	2.85	2.90			
Fall 2022	4	9	3	0	0	**16**	3.06	2.96	0.9727	1	**0.0071**
Fall 2019	9	18	5	0	3	**35**	2.86	2.96			

Another assessment (Chi-square Goodness-of-fit test) was performed based on the weighted average GPA for both the options and for all eight semesters combinedly, and the data is presented in Table 5. A *p*-value of ***1.0000*** was obtained which is greater than both 0.05 ($\alpha = 5\%$) and 0.01 ($\alpha = 1\%$). A χ^2-value of ***0.0928*** was also obtained. For a degree of freedom of 7, the critical values for χ^2 are 14.14 (for $\alpha = 5\%$) and 18.5 (for $\alpha = 1\%$). The chi-square (χ^2) value obtained from the test is less than the critical values of both for $\alpha = 5\%$ and $\alpha = 1\%$. Therefore, from both the χ^2-value and *p*-value point of views, the null hypothesis cannot be rejected. That means no significant differences exist in the grades with and without ICPS options.

Table 5: Assessment based on weighted average GPA using Chi-square Goodness-of-fit test

Semester	Observed GPAs	Expected GPAs	Statistics
Fall 2021	2.89	2.82	***p-value*** *= 1.0000* ***DF*** *= 7* χ^2***-value*** *= 0.0928*
Fall 2018	2.88	2.82	
Spring 2022	2.43	2.82	
Spring 2019	2.65	2.82	
Summer 2022	2.94	2.82	
Summer 2019	2.85	2.82	
Fall 2022	3.06	2.82	
Fall 2019	2.86	2.82	
Total	**22.56**	**22.56**	

Since ANOVA and χ^2-test agreed, practically there is no need to run *t*-Test and *F*-test for further confirmation; however, *t*-Test and *F*-test for the two groups, w/ICPS, and w/o ICPS (Table 2), were run for additional verification. The *t*-Test performed on Weighted Average GPA ($p=0.065$, $t=2.348$, $t_{critical}=2.571$) and the *F*-test (($p=0.0766$, $F=6.675$, $F_{critical}=9.2766$) also agreed with ANOVA and χ^2-test and confirmed that the observed difference between the sample means is not convincing enough to say that the average weighted GPA between with and without ICPS options differ significantly. Statistically, this study contradicts with the summary results of 225 studies reported by Freeman et al.[10] and agrees with a study by the author [14].

Students' perception was compared with their performance (weighted average GPA), as shown in Figure 3. For Figure 3, the weighted average GPAs were adjusted to a 5-point scale to match the Likert scale. As mentioned earlier, the students' perceptions were collected via a survey with three questions: Q1 - Did tests reflect the material covered in the class?, Q2 - Is there a good agreement between the course outline (syllabus) and the course content?, and Q.3 - Do you think that in-class problem-solving helped you do better in the course and learning the course materials? From Figure 3(a) there is no clear correlation between students' perceptions and performance in terms of weighted average GPA. However, Figure 3(b) shows positive correlations for Q3, that is the GPA increases with the increase of Q3 perceptions, whereas Q1 and Q2 show negative or flat correlations.

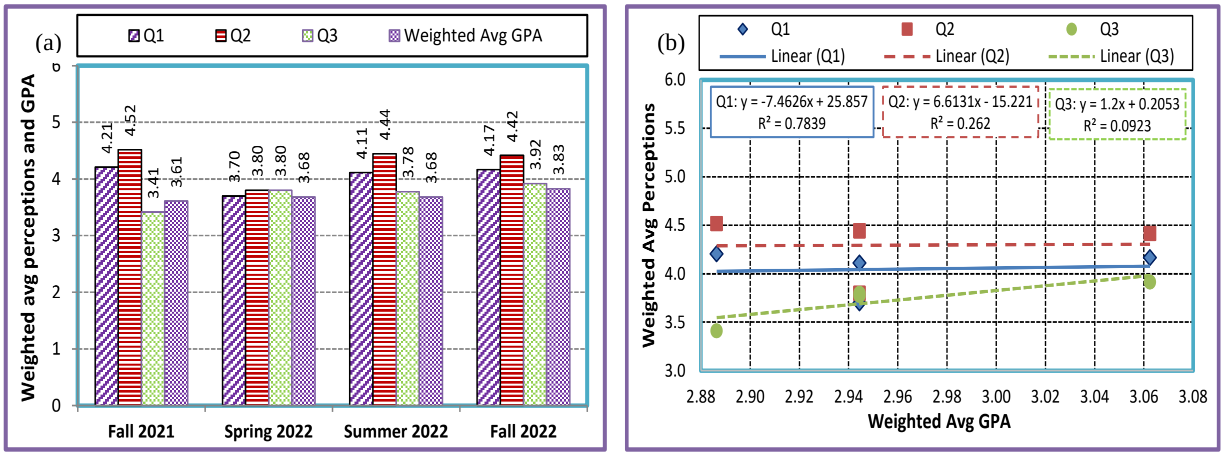

Figure 3: Correlations of students' perceptions and performances

Study Limitations

The main source of bias for this study could be that the author was the only person who designed this study, conducted the survey, collected and analyzed the semester-end survey and the final grade data. The evident conflict of interests and potential unconscious bias could genuinely affect the validity of this study. The other limitation could be the size of the data, as it is for only one course and four semesters. Several subjects in engineering fields, more faculty collaboration, and more than four semesters of study can generate more data and could make the study more dependable and further conclusive. Another important limitation could be the students’ negative responses to active teaching strategies. Student resistance to active learning, including reasons for this opposition and strategies to prevent or respond to it was not considered. Recognizing factors that lead to students’ resistance to active learning is important to mitigating these barriers to learning[12].

Summary and Conclusions

In this paper, an effort was made to assess the perceptions and attitudes of students, which influence the learning environment as well as the effect of in-class problem-solving activities in engineering. The courses `Intro to Environmental Engineering' from the Civil and Environmental Engineering curriculum was used to conduct this study. In-class problem-solving as a part of course delivery option was performed in each topic of the courses. At the end of the semester, a survey with three Likert-scale questions was conducted. The data was analyzed to determine the students’ perceptions and attitudes about in-class problem-solving activities in terms of their learning experience and performance. The final grades were analyzed and compared with previous similar semesters’ data without in-class problem-solving activities for four semesters (fall 2021, spring, summer and fall 2022) to understand the effect of in-class problem-solving activities. Although statistically, the differences were not significant, students’ perceptions and attitudes were positive and indicated the effectiveness of in-class problem-solving activities. In terms of the weighted average GPA based on the course grades students’ performances were better with in-class problem-solving activities course-setting than that of without in-class problem-solving activities course-setting although other statistical analyses such as ANOVA, χ^2-test, t-Test, F-test disagreed. Negative to flat correlations were observed among the first two perception scenarios (Q1 - tests reflected the material covered in the class and Q2 - there was a good agreement between the course outline and the course content) and weighted average GPA, whereas a positive correlation was observed between in-class problem-solving (Q3 - in-class problem-solving helped you do better in the course and learn the course materials) and weighted average GPA. Although statistical differences were not significant, students' perceptions and attitudes were positive and indicated the effectiveness of in-class problem-solving activities in improving the overall performance.

Disclaimer: Partial data (fall 2021) was presented in ASEE 2022 Conference held in Minneapolis, Minnesota along with another construction management course data.

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M. A. Karim

Dr. Karim spent about six years as a full-time faculty at the Bangladesh University of Engineering and Technology (**BUET**) after he graduated from the same university in 1989. He came to the USA in 1995 and finished his PhD in Civil/Environmental Engineering from Cleveland State University in 2000. He worked for about three years for ALLTEL Information Services in Twinsburg, Ohio, as an Applications Programmer. Then he worked for about eight years (in two separate times) for the Virginia Department of Environmental Quality (**VDEQ**) as a Senior Environmental Engineer and taught at Virginia Commonwealth University (**VCU**) as an Affiliate Professor before he went to Trine University in January 2008, as a full-time faculty of Civil & Environmental Engineering. He taught part-time at Purdue University Fort Wayne (**PFW)** while employed at Trine University. During his time at Trine University, he taught an online course for VCU. He also taught at Stratford University, Richmond, Virginia campus as an adjunct faculty while working for VDEQ. Since the fall of 2011, Dr. Karim has been working for Kennesaw State University (**KSU**), Marietta Campus, Georgia, as a full-time faculty in Civil and Environmental Engineering. He served as an Assistant Department Chair and an Interim Department Chair of Civil and Environmental Engineering Department at KSU. He is a registered professional engineer for the State of the Commonwealth of Virginia and the state of Georgia. He has more than forty journal and proceeding publications and three professional reports in soil and sediment remediation, environmental management, waste treatment and management, wastewater treatment, statistical hydrology, engineering education including project- and problem-based learning (PBL). He is a fellow of the American Society of Civil Engineers (**F.ASCE**), the American Society for Engineering Education (**M.ASEE**), and a Board-Certified Environmental Engineer (**BCEE**) from the American Academy of Environmental Engineers and Scientists (**AAEES**). He is also an ABET EAC Program Evaluation Volunteer (ABET EAC PEV) for both the civil engineering and environmental engineering programs.