2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #32413

Effectiveness of a Software-based Service-learning Project in First-year Seminar Course for Engineering Freshmen During the COVID-19 Pandemic

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1. Background and Motivation

The Service-Learning Project (SLP) component in an introductory engineering freshmen course at the University requires that students complete an engineering project from inception to implementation during their first semester. The project requirements are derived from the specific needs of a non-profit community organization. Under normal circumstances, the SLP activities would produce a physical product or working prototype that would be installed at a community site. In 20/FA, however, due to the COVID-19 pandemic, various cautionary measures and guidelines were put in place by the University to prevent the spread of the virus within the campus community. This hampered the usual ways of carrying out SLP activities in this course. Under these circumstances, after much deliberation among the course instructors, a simpler but still meaningful project concept was devised in an effort to mitigate the impacts on SLP activities.

One of the main criteria for formulation of the SLP in 20/FA was enabling students to collaboratively implement their projects in a virtual environment while minimizing the need for close physical contact, as was typically needed for the SLP project in previous years. To meet his criterion, a software-based SLP was defined with the objective to produce a graphical user interface (GUI) that would address the needs of an environmental non-governmental organization (NGO). One of the missions of this NGO is fostering a partnership between the private sector and a state government's department in charge of conservation and natural resources in one of the Great Lakes areas to enhance educational programming. More specifically, the partner organization operates a set of buoys and weather stations in Lake Erie to collect environmental data. To create educational material, this NGO needed a data dashboard to process the raw data, perform statistical analysis, and generate summary reports on an ongoing basis. The students were free to use their preferred software package or online cloud service to develop a data dashboard with data processing capabilities; however, Microsoft Excel was offered as the primary tool, because it was available to students by the University free of charge, and all instructors were able to provide technical support. Otherwise, other software packages could have been used similarly. The authors do not advocate for a certain commercial software package.

In this paper, we assess 1) the pros and cons of such a project as an SLP, 2) the effectiveness of teamwork in a partly virtual environment, 3) student awareness of environmental monitoring in a real-world situation, and 4) student perception on significance of the GUI development SLP compared to traditional service-learning projects. We also assess the use of self-regulated learning (SRL) skills under the current circumstances and compare them with the assessment results previously reported in the literature.

2. Description and Justification of Methodology

2.1. FYSE Course Setup for SLP

The overall course set-up for this study is similar to that described in [1] as the SLP framework in 20/FA was adopted for the same course. While the work in [1] was focused on student use of self-regulated learning skills during SLP activities in the First-Year Seminar in Engineering

(FYSE) course in 18/FA, the current study is focused on the effectiveness of a software-based project as an SLP. Details of the course can be found in [1], but a brief synopsis is provided here for completeness of the discussion within this paper. The FYSE course is a 2-credit hour introductory course that all freshmen in engineering at the University are required to take in the first semester of the freshmen year. Part of the coursework is the service-learning facilitated in a semester-long effort. The service-learning project is carried out by dedicating 11 class sessions out of a total of 28, as well as the additional time student spent out of the designated class time. Final presentations are required in lieu of a final exam. The activity schedule is shown in Table 1 for 20/FA. It must be noted that 20/FA started and finished earlier, from Aug. 10 to Nov. 16, than the University's typical schedule to mitigate the increased risk of COVID-19 spread during the cold season. The class session introducing the service-learning to the students was considered as Phase 1. As part of Phase 1, students are divided into teams of 3~4 students. Phase 2 is for specification development leading to an understanding of what is needed, considering the context, stakeholders, and requirements, and why the current art doesn't meet the community's need. In this phase, the students also develop measurable criteria for evaluation of their design later on. Phase 3 involves conceptual design expanding the design space to include several possible solutions and selection of the "best" solution to move forward. Team proposals are then presented in an oral presentation session in the middle of the semester, and their working prototypes are completed by the end of the semester.

Table 1. Example of SLP Activity Schedule

Session	Date	Topic
3	8/17/2020	Introduction to SLP (Phase 1)
7	8/31/2020	SLP Phase 2: Specification development
10	9/14/2020	SLP Phase 3: Conceptual design
14	9/28/2020	SLP Proposal Presentations
16	10/5/2020	SLP Implementation
18	10/12/2020	SLP Implementation
24	11/2/2020	SLP implementation (address any issues)
25	11/6/2020	SLP Implementation
26	11/9/2020	SLP Implementation
27	11/13/2020	SLP Implementation
28	11/16/2020	SLP Assessment
Finals	11/20/2020	SLP Final Presentation

In 20/FA, the FYSE course was run in three concurrent sections by three full-time engineering faculty members for 67 students, following the milestone schedule shown in Table 1. More specifically, the first section of the course had 23 students divided into seven teams. There were three students in biomedical engineering, three in cybersecurity/engineering, three in electrical and computer engineering, two in environmental engineering, two in industrial engineering, nine in mechanical engineering, and one in software engineering. Among them, the number of female students was ten (43.5% of the enrollment in this section). The second section of the course had 23 students with majors distributed as follows: six students in biomedical engineering, four in cybersecurity/engineering, two in electrical and computer engineering, and eleven in mechanical engineering. Among them, the number of female students was four (17.4% of the section enrollment). The third section of the course had 21 students in total, with three students in biomedical engineering, nine in cybersecurity/engineering, two in electrical and computer engineering, three in environmental engineering, and four in mechanical engineering. Among them, the number of female students was five (23.8% of the section enrollment), making the overall counts of female students 18 (or 26.9%) among 67 students in the course.

2.2. Service-Learning Project: Setup

The SLP in 20/FA was in partnership with the Tom Ridge Environmental Center (TREC) Foundation. As a research wing of the TREC, the Regional Science Consortium (RSC) [2], located on the shores of Lake Erie and not directly affiliated with an institution, is a 501(c)3 non-profit organization and a consortium of institutions. It facilitates research, education, and collaborations with RSC members while responsible for the operation and maintenance of several buoys near/on Lake Erie, which measure environmental parameters in real time. The data being collected include, among others, average and maximum wave heights, wave period, wave direction, water temperature, specific conductivity, pH level, turbidity, dissolved oxygen, as well as traditional weather parameters such as air temperature, wind speed, wind direction, relative humidity, barometric pressure, and solar radiation. These data are stored on a 3rd party server that currently has limited data visualization capability for visitors to the TREC and adjacent Presque Isle State Park.

The RSC needed a data visualization tool, i.e., dashboard, to visualize, at least, the following parameters: water temperature, dissolved oxygen, wave height, and air temperature, among others. It was required that the dashboard be able to show the data collectively or for each station/buoy and for any desired date/time range. The RSC was also interested in knowing if the differences in parameter values between the years are significant.

Data analysis tools to be utilized included MS Excel, MATLAB, other free data analysis technology, Amazon Web Services (AWS), and Google Data Studio. For the first semester in engineering school, the students were not expected to possess, or begin with, strong programming/ software skills to successfully complete the project but they were encouraged to learn one of the software tools as part of the effort. As such, while a specific choice was left with the students for their project formulation and design and the technical support from the instructors was intentionally limited, a tutorial session on MS Excel was provided in a class period. Also, online resources, including links to a set of YouTube tutorial videos relevant to dashboard development in

Table 2. SLP Evaluation Criteria

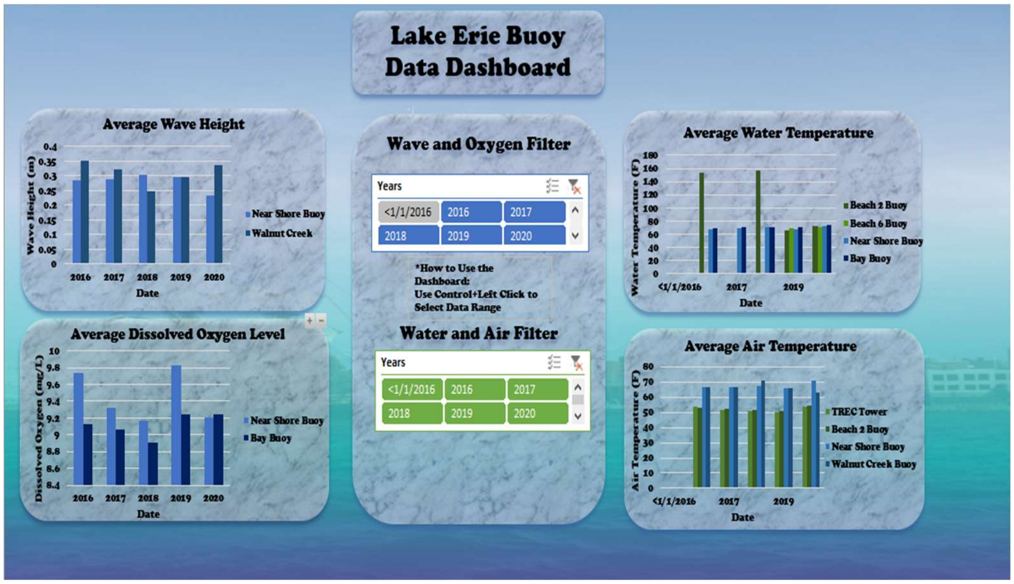
Criteria	**Score**
Creative Design: • Explore different solutions, and make a case for a particular solution • It is not similar to any of the existing models; creativity is evident in the design	0-20
User friendly: • The design takes into account that users may be young or old, tech-proficient or not so tech-proficient? Can design be used by the average person?	0-10
Mission: • Relates to the mission of the non-profit organization/ stakeholders?	0-10
Feasibility: • Is it realistic to implement (consider design, skills, timeline)?	0-10
Additional feature(s) useful to the stakeholder: • Does the design meet the minimum requirement? • Does it incorporate additional features?	0-20
Requirements • The design must be specific for the purpose and user requirements	0-30
Total Points	100

Excel as well as an easy-to-follow Excel template of dashboard implementation, were made available (for example, see [3],[4]). For those who would choose MATLAB as their software tool for the project, learning MATLAB programming was facilitated by synchronizing the implementation timeline somewhat with the pace of a separate freshmen course on MATLAB that all engineering freshmen take in the same semester within the student discipline's curriculum.

The criteria shown in Table 2 were used for the evaluation of the project proposals and final implementations. Also, as a means to promote, encourage, and ensure proper progress with time, a set of short assignments were administered along the way, such as three progress reports during the project design phase (i.e., until Session 14 shown in Table 1), three status reports during the implementation period (i.e., Sessions 16~28 as shown in Table 1), and also two peer assessments on teamwork within each project group.

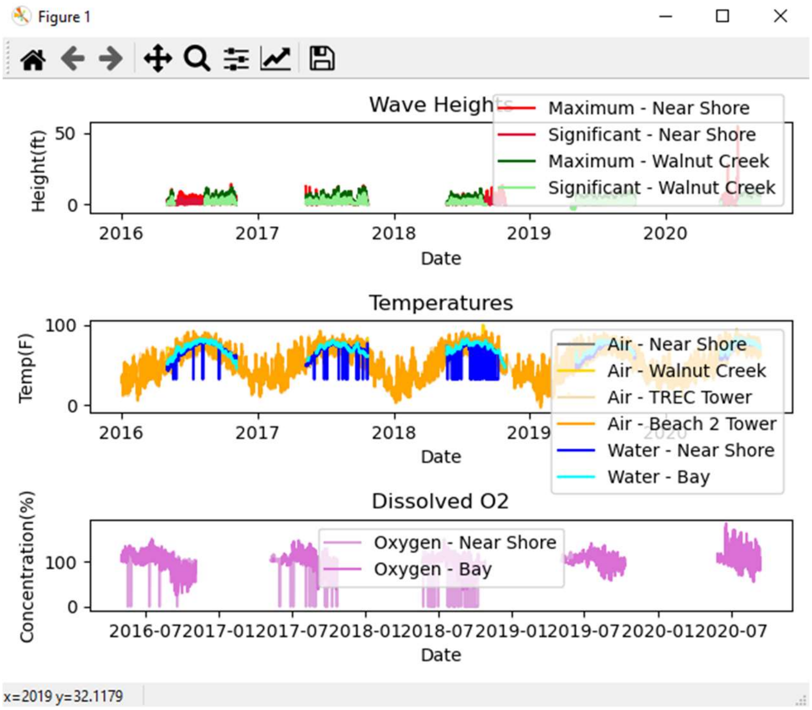
2.3. Service-Learning Project: Examples of Final Implementation

Figure 1 shows two examples of the final implementation of dashboard GUI. The dashboard in Figure 1(a) was implemented in Excel by a group of 3 students. This group wanted a simple and appealing user interface displaying four different data (wave height, dissolved oxygen, water temperature, and air temperature) with bar charts. In the center of the GUI, two filters were placed for users to select data ranges for display, and user-friendly instructions were provided between the filters, i.e., "How to Use the Dashboard: Use Control+Left Click to Select Data Range." For the background image, the Bicentennial Tower and the US Brig Niagara (a wooden-hulled snow-brig) were used for an aspect of creative design. In contrast, the dashboard in Figure 1(b) was implemented in Python by another group of 3 students. This GUI also processes four different data as in the first example, i.e., wave height, dissolved oxygen, water temperature, and air temperature. This group wanted to offer three special features such as magnifying, changeable layout, and customizable graphs in color, displayed data, time period, and spacing, and was able to make this GUI run as a standalone application with an executable (.exe) file for easy deployment on different computers.



*How to Use the Dashboard: Use Control+Left Click to Select Data Range

(a) Dashboard implemented in Excel



(b) Dashboard implemented in Python

Figure 1. Examples of final implementation of dashboard GUI.

2.4. Assessment of Effectiveness

To gauge the effectiveness of the software-based SLP during the COVID-19 pandemic, we considered i) student learning outcomes and student perceptions and ii) student use of self-regulated learning skills. Data for assessment were collected from two sets of survey instruments covering these aspects.

To assess student learning outcomes, we adopted a small set of student learning outcomes defined by ABET/EAC. Subsequently, we came up with a 7-question survey questionnaire by slightly modifying the one used in [5]. In this questionnaire, shown in Table 3, each student outcome was asked in two ways: a) if the SLP activities *provided* opportunities for the student to improve on these learning outcomes and b) if the student *has actually improved* by participating in the SLP activities. Also, for each student outcome, a blank space was provided for any written comments. Three additional questions were included to gauge student perceptions on the effectiveness of the software-based SLP in facilitating teamwork in a partly virtual environment, improving student awareness of environmental monitoring in a real-world situation, and the significance of the GUI development compared to traditional service-learning projects that are normally physically installed at community sites. For quantitative analysis, we used five possible responses to each question and converted them to numerical scores on a scale of 1 to 5 as follows: 1-Strongly Disagree, 2-Moderately Disagree, 3- Neutral, 4- Moderately Agree, 5- Strongly Agree.

We also assessed the use of self-regulated learning (SRL) skills in this software-based SLP and compared the results with those previously reported in the literature [1] that was also studied for freshmen's SLP activities in traditional circumstances but based on physical in-lab activities. SRL is regarded as a complex repository of knowledge and skills for planning, implementing,

Table 3. Questionnaire on Student Learning Outcomes

Question
Q1-a: The Service-Learning Project activities in FYSE **provided** me with an opportunity to improve my ability to **apply knowledge of mathematics, science, and engineering**.
Q1-b: Participating in the Service-Learning Project activities in FYSE, I have **improved** my ability to apply knowledge of mathematics, science, and engineering.
Q2-a: The Service-Learning Project activities in FYSE **provided** me with an opportunity to improve my ability to **apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors**.
Q2-b: Participating in the Service-Learning Project activities in FYSE, I have **improved** my ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
Q3-a: The Service-Learning Project activities in FYSE **provided** me with an opportunity to improve my ability to **communicate effectively with a range of audiences**.
Q3-b: Participating in the Service-Learning Project activities in FYSE, I have **improved** my ability to communicate effectively with a range of audiences.
Q4-a: The Service-Learning Project activities in FYSE **provided** me with an opportunity to improve my ability to **recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts**.
Q4-b: Participating in the Service-Learning Project activities in FYSE, I have **improved** my ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
Q5-a: The Service-Learning Project activities in FYSE **provided** me with an opportunity to improve my ability to **function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives**.
Q5-b: Participating in the Service-Learning Project activities in FYSE, I have **improved** my ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
Q6-a: The Service-Learning Project activities in FYSE **provided** me with an opportunity to improve my ability to **develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions**.
Q6-b: Participating in the Service-Learning Project activities in FYSE, I have **improved** my ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
Q7-a: The Service-Learning Project activities in FYSE **provided** me with an opportunity to improve my ability to **acquire and apply new knowledge as needed, using appropriate learning strategies**.
Q7-b: Participating in the Service-Learning Project activities in FYSE, I have **improved** my ability to acquire and apply new knowledge as needed, using appropriate learning strategies.
Additional Questions
Q8: The Service-Learning Project activities in FYSE **provided** me with an opportunity to **improve my awareness of environmental monitoring in a real-world situation**.
Q9: This software-based Service-Learning Project activities in a partly virtual environment **were effective in promoting teamwork**.
Q10: For a Service-Learning Project in FYSE, I **would have liked a traditional service-learning project** that would require activities in an actual laboratory setting and be physically installed at a community site, **more than this non-laboratory-based GUI development project**.

monitoring, evaluating, and continually improving the learning process. As it is commonly agreed that self-regulation is a good predictor of student's academic success, in the literature, SRL skills had been assessed in introductory freshmen courses with small engineering projects as part of the coursework (e.g., see [1],[6]). More comprehensive studies on SRL had been conducted and reported in the literature, but details are omitted for brevity in this paper. One of the key observations made in the prior work was that freshmen in engineering generally used a reasonable level of SRL skills while carrying out their respective engineering projects. A comparison of our current results with the previous ones is of interest in this paper.

Data collection for the assessment of SRL skills is, in general, carried out in the form of surveys in the literature; however, the actual questionnaires vary depending on the purposes and analytical models. In this paper, as our study was focused on the use of SRL skills in engineering design activities around SLP, we adopted a relatively simple survey instrument that was developed and validated particularly for assessment of the use of SRL skills in engineering design [7]. It captures student's perception of metacognition along the cycle of engineering design which typically includes problem definition, conceptual design, preliminary design, detailed design, and design communication. This survey instrument was previously utilized in some prior pilot studies on the use of SRL skills in engineering design in classroom settings. In these pilot studies, five SRL features were used: 1) task interpretation, 2) planning strategies, 3) cognitive actions, 4) monitoring and fix-up strategies, and 5) criteria of success. Each SRL feature was further split into two subcategories of activities in *design process* and *team management*. The resulting ten questions of the questionnaire are a subset of the Engineering Design Metacognitive Questionnaire (EDMQ) [7] and are considered suitable for evaluating the use of SRL skills in engineering project activities. The text for those ten questions of the questionnaire can be found in [1]. As in the previous studies, we used four possible responses to each question and converted them to numerical scores on a scale of 1 to 4 as follows: 1-Almost Never, 2-Sometimes, 3-Often, 4-Almost Always.

3. Results and Data Analysis

3.1. Effectiveness in Improving Student Outcomes

A survey was conducted at the end of the semester during the 28th class session in all three sections. The numbers of valid responses were 22 out of 23 students in section 1, 17 out of 23 students in section 2, and 18 out of 21 students in section 3. The surveys were anonymous, and some students turned them in with blank responses, which were subsequently omitted for the statistical analysis. The survey results are summarized in Table 4.

As our numerical assessment scale was effectively a Likert scale which is known to be a bipolar scaling method, we considered scores above the median score of 3.0 as *effective* (denoted by green cells in Table 4) and scores below the median value as *ineffective* (denoted by yellow cells in Table 4). Also, for the purpose of gauging student perceptions on improving student outcomes, we also ignored any possible causes that could have biased student responses in our assessment such that the statistical results could be used for us to develop our intuition. Then, a few observations could be made from the average scores in Table 4.

First, from the all-section average scores, the scores of Q1 (a) and (b) of 2.89 and 2.86, respectively, indicate that this software-based GUI development project was not effective in facilitating students to improve in applying knowledge of mathematics, science, and engineering. Also, the all-section average of Q4(a) of 2.96 indicates that this project was not effective in helping students recognize ethical and professional responsibilities in engineering situations and make informed judgments considering the impact of engineering solutions in global, economic, environmental, and societal contexts. All other all-section average scores were above 3.0. That is,

Table 4. Summary of Survey Results on Student Outcomes

Q#	Section 1		Section 2		Section 3		All Sections	
	Av.	Std. Dev	Av.	Std. Dev	Av.	Std. Dev	Av.	Std. Dev
Q1-a	2.77	1.20	2.82	1.10	3.11	0.94	2.89	1.10
Q1-b	2.64	1.26	2.88	0.96	3.11	0.87	2.86	1.08
Q2-a	2.91	1.08	3.12	0.83	3.61	0.76	3.19	0.96
Q2-b	2.73	1.01	3.18	0.78	3.67	0.88	3.16	0.99
Q3-a	3.32	1.14	3.12	1.02	3.89	0.74	3.44	1.04
Q3-b	3.55	1.08	3.18	1.10	3.67	0.82	3.47	1.03
Q 4-a	2.50	1.16	3.24	0.55	3.28	0.93	2.96	1.01
Q4-b	2.64	1.15	3.41	0.60	3.33	0.88	3.09	1.00
Q5-a	3.91	1.08	3.88	0.58	3.83	0.83	3.88	0.88
Q5-b	4.00	1.00	3.53	0.85	4.06	0.78	3.88	0.92
Q6-a	3.18	1.15	3.12	1.08	3.67	1.00	3.32	1.11
Q6-b	3.36	1.23	3.12	1.13	3.78	0.97	3.42	1.15
Q7-a	3.41	0.78	3.41	0.77	3.61	0.68	3.47	0.75
Q7-b	3.50	0.84	3.35	0.84	3.56	0.76	3.47	0.82
Q8	3.00	1.17	2.88	0.96	3.28	1.15	3.05	1.11
Q9	2.86	1.32	3.12	1.13	3.17	1.17	3.04	1.23
Q10	4.64	0.93	4.29	0.96	3.83	1.26	4.28	1.10

this project helped students apply engineering design to produce solutions (Q2), communicate effectively with a range of audiences (Q3), function effectively on a team (Q5), develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions (Q6), and acquire and apply new knowledge as needed, using appropriate learning strategies (Q7).

Second, from the average scores of individual class sections, one can notice that section 1 scored below 3.0 in Q1, Q2, and Q4, while section 2 scored below 3.0 only in Q1, and section 3 scored none below 3.0. Possible reasons for these differences may be attributed to primarily the following aspects: 1) instructor's style in interacting with students to facilitate the project activities and 2) the composition of the student majors in a section. While it is well known that instructor's style influences the outcome of student learning outcomes, the composition of student majors interestingly led to opposite perceptions in our case. That is, in section 3, there were 9 (or 42.8%) cybersecurity/engineering majors who were mainly comfortable with the use of computer software tools and thus enjoyed the software-based SLP. On the other hand, section 2 had 4 (or 17.4%) cybersecurity/engineering majors, and two of them were relatively comfortable with the use of software tools but expressed that there was not much to learn from the SLP. Section 1 had 3 (or 13.0%) cybersecurity/engineering majors, and only one of them was fairly comfortable with the use of software tools, while the other two were not so competent in the use of software tools. Most of the other major students were considered a novice to use of computer software tools available for the project and didn't relate the project to their majors to improve student learning outcomes.

Similarly, on Q8, Q9, and Q10 that were intended to gauge student perceptions about the effectiveness of the software-based GUI development as an SLP, one can note that aggregated all-section averages are above the 3.0 threshold in Q8 and Q9 while the average scores for individual sections vary from 2.88 to 3.28 for Q8 (awareness of environmental monitoring in a real-world situation), from 2.86 to 3.17 for Q9 (teamwork in a partly virtual environment). However, notably, the average scores of Q10 (traditional service-learning project) in all three sections are substantially higher than those for all other questions, leading to an all-section average of 4.28. This indicates that students would like traditional service-learning projects more than non-physical laboratory-based GUI development.

3.2. Effectiveness in Facilitating Use of SRL Skills

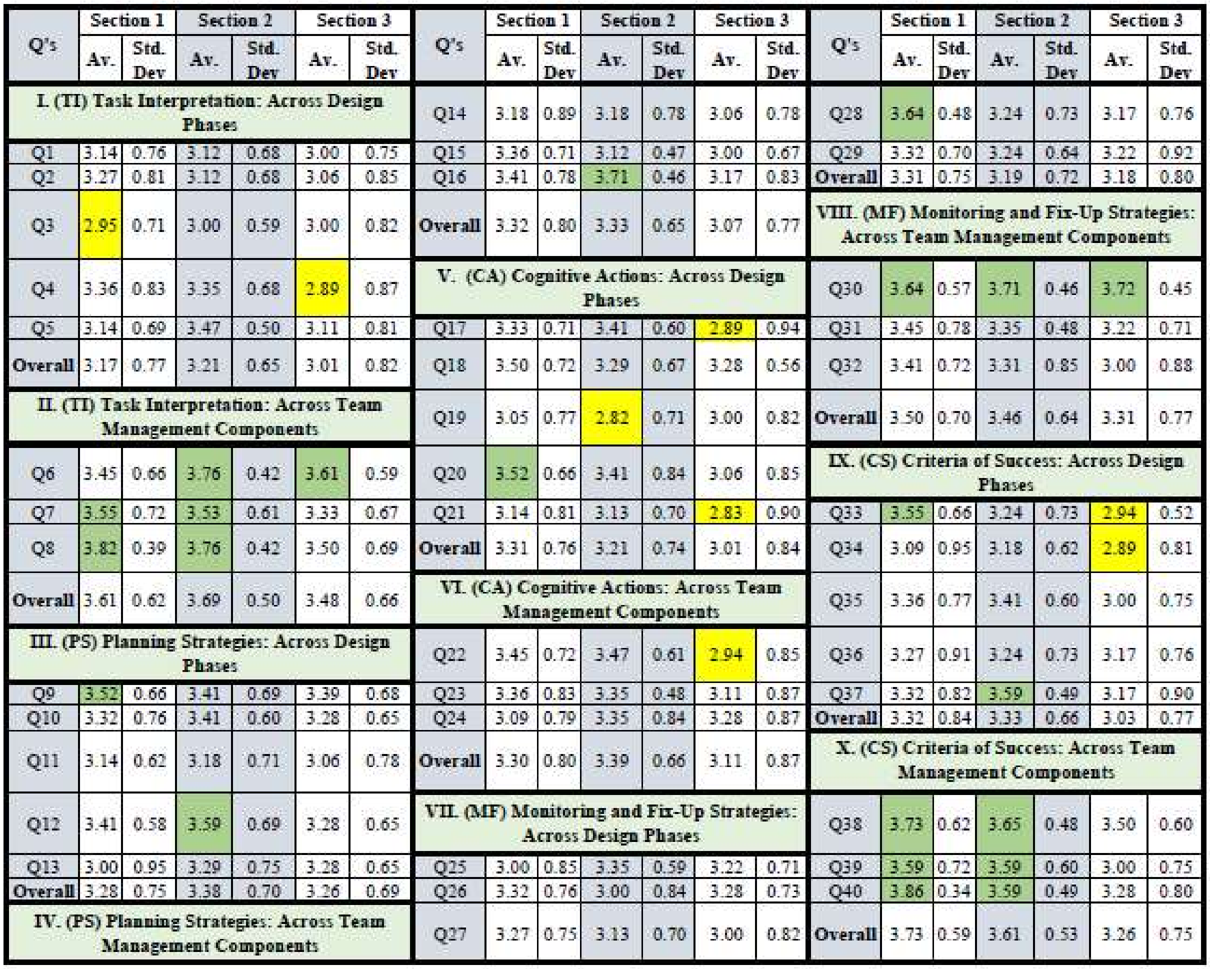
A second survey was also conducted at the end of the semester during the 28th class session in all three sections. The numbers of valid responses were the same as the first survey discussed above, i.e., 22 out of 23 students in section 1, 17 out of 23 students in section 2, and 18 out of 21 students in section 3. The survey results are summarized in Table 5. For intuitive understanding from these numerical results, we considered that, as in [1], the average scores greater than or equal to 3.0 and less than 3.5 represent a "reasonable level" in using SRL skills; average scores below 3.0 represent "room for improvement"; and average scores greater than or equal to 3.5 represent a "highly desirable" level. This average score of 3.0 as the threshold was our own choice, without rigorous validation, based on the scores assigned to the four possible answers. Omitting a neutral from the possible responses, we assumed that two responses of Often and Almost Always indicate a good use of the SRL skills embedded in individual questions.

Looking at individual section scores presented in Table 5, one can notice that the students in section 1 responded that they effectively used the SRL skills in most questionnaire items except for Q3 (av. 2.95; analyze the chosen design model; marked in yellow). Furthermore, they scored above 3.5 in nine items (marked in green), i.e., Q7 (seek relevant resources), Q8 (do my fair share in team's effort), Q9 (read design description to identify design goals), Q20 (fine-tune the design), Q28 (judge whether further adjustments are needed), Q30 (think about how much time is left when working with my team), Q33 (develop a list of final design goals), Q38 (ensure that my contribution had helped my team), Q39 (find and use relevant resources), and Q40 (able to do my fair share in my team's accomplishment).

The students in section 2 scored below 3.0 in one item, i.e., Q19 (av.2.82, marked in yellow) and scored above 3.5 in ten items (marked in green), i.e., Q6 (ensure that my contribution will deliver the design tasks in a timely manner), Q7, Q8, Q12 (identify necessary adjustments need to optimize the chosen design), Q16 (identify and clarify my part in the team's effort), Q30, Q37 (able to produce a final written design report, etc. to the client), Q38, Q39 (find and use relevant resources), Q40. On the other hand, the students in section 3 scored below 3.0 in six items (marked in yellow), i.e., Q4 (av. 2.89), Q17 (av. 2.89), Q21 (av. 2.83), Q22 (av. 2.94), Q33 (av. 2.94), and Q34 (2.80) and score above 3.5 in two items (marked in green), i.e., Q6, Q30.

Now, looking at scores across the course sections for similarities and dissimilarities of student perception on the use of SRL skills, one can see that, from the average scores of individual questions, the students in sections 1 and 2 scored above 3.5 in five items, i.e., Q7, Q8, Q30, Q38, and Q40 and all three section students scored above 3.5 in one item, i.e., Q30. From the category's overall averages, one can see that both sections 1 and 2 showed similar averages while section 3 showed a relatively lower average near the 3.0 threshold in four categories, I (3.17/3.21/3.01; task interpretation across design phase), IV (3.32/3.33/3.07; planning strategies across team management component), V (3.31/3.21/3.01; cognitive action across design phase), and IX (3.32/3.33/3.03; criteria of success across design phase).

Table 5. Summary of Survey Results on Use of SRL Skills – 20/FA



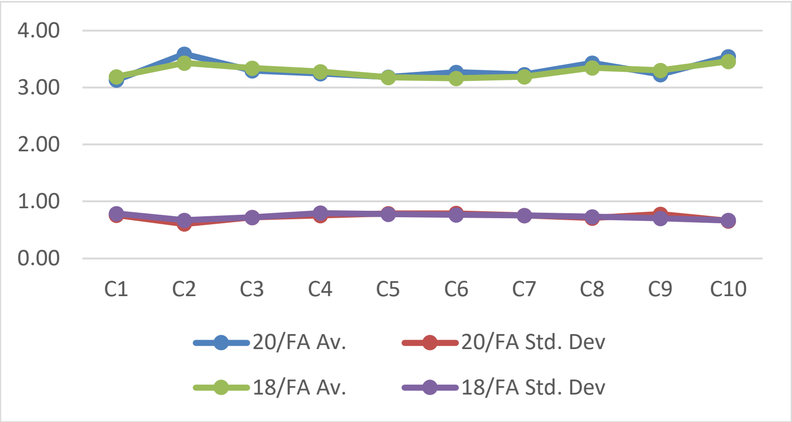
Q's	Section 1		Section 2		Section 3	
	Av.	Std. Dev	Av.	Std. Dev	Av.	Std. Dev
I. (TI) Task Interpretation: Across Design Phases						
Q1	3.14	0.76	3.12	0.68	3.00	0.75
Q2	3.27	0.81	3.12	0.68	3.06	0.85
Q3	2.95	0.71	3.00	0.59	3.00	0.82
Q4	3.36	0.83	3.35	0.68	2.89	0.87
Q5	3.14	0.69	3.47	0.50	3.11	0.81
Overall	3.17	0.77	3.21	0.65	3.01	0.82
II. (TI) Task Interpretation: Across Team Management Components						
Q6	3.45	0.66	3.76	0.42	3.61	0.59
Q7	3.55	0.72	3.53	0.61	3.33	0.67
Q8	3.82	0.39	3.76	0.42	3.50	0.69
Overall	3.61	0.62	3.69	0.50	3.48	0.66
III. (PS) Planning Strategies: Across Design Phases						
Q9	3.52	0.66	3.41	0.69	3.39	0.68
Q10	3.32	0.76	3.41	0.60	3.28	0.65
Q11	3.14	0.62	3.18	0.71	3.06	0.78
Q12	3.41	0.58	3.59	0.69	3.28	0.65
Q13	3.00	0.95	3.29	0.75	3.28	0.65
Overall	3.28	0.75	3.38	0.70	3.26	0.69
IV. (PS) Planning Strategies: Across Team Management Components						
Q14	3.18	0.89	3.18	0.78	3.06	0.78
Q15	3.36	0.71	3.12	0.47	3.00	0.67
Q16	3.41	0.78	3.71	0.46	3.17	0.83
Overall	3.32	0.80	3.33	0.65	3.07	0.77
V. (CA) Cognitive Actions: Across Design Phases						
Q17	3.33	0.71	3.41	0.60	2.89	0.94
Q18	3.50	0.72	3.29	0.67	3.28	0.56
Q19	3.05	0.77	2.82	0.71	3.00	0.82
Q20	3.52	0.66	3.41	0.84	3.06	0.85
Q21	3.14	0.81	3.13	0.70	2.83	0.90
Overall	3.31	0.76	3.21	0.74	3.01	0.84
VI. (CA) Cognitive Actions: Across Team Management Components						
Q22	3.45	0.72	3.47	0.61	2.94	0.85
Q23	3.36	0.83	3.35	0.48	3.11	0.87
Q24	3.09	0.79	3.35	0.84	3.28	0.87
Overall	3.30	0.80	3.39	0.66	3.11	0.87
VII. (MF) Monitoring and Fix-Up Strategies: Across Design Phases						
Q25	3.00	0.85	3.35	0.59	3.22	0.71
Q26	3.32	0.76	3.00	0.84	3.28	0.73
Q27	3.27	0.75	3.13	0.70	3.00	0.82
Q28	3.64	0.48	3.24	0.73	3.17	0.76
Q29	3.32	0.70	3.24	0.64	3.22	0.92
Overall	3.31	0.75	3.19	0.72	3.18	0.80
VIII. (MF) Monitoring and Fix-Up Strategies: Across Team Management Components						
Q30	3.64	0.57	3.71	0.46	3.72	0.45
Q31	3.45	0.78	3.35	0.48	3.22	0.71
Q32	3.41	0.72	3.31	0.85	3.00	0.88
Overall	3.50	0.70	3.46	0.64	3.31	0.77
IX. (CS) Criteria of Success: Across Design Phases						
Q33	3.55	0.66	3.24	0.73	2.94	0.52
Q34	3.09	0.95	3.18	0.62	2.89	0.81
Q35	3.36	0.77	3.41	0.60	3.00	0.75
Q36	3.27	0.91	3.24	0.73	3.17	0.76
Q37	3.32	0.82	3.59	0.49	3.17	0.90
Overall	3.32	0.84	3.33	0.66	3.03	0.77
X. (CS) Criteria of Success: Across Team Management Components						
Q38	3.73	0.62	3.65	0.48	3.50	0.60
Q39	3.59	0.72	3.59	0.60	3.00	0.75
Q40	3.86	0.34	3.59	0.49	3.28	0.80
Overall	3.73	0.59	3.61	0.53	3.26	0.75

All three sections showed an overall average well above 3.0 in six categories, i.e., II (3.61/3.69/3.48; task interpretation across team management component), III (3.28/3.38/3.26; planning strategies across design phase), VI (3.3/3.39/3.11; cognitive actions across team management components), VII (3.31/3.19/3.18; monitoring and fix-up strategies across design phases), VIII (3.5/3.46/3.31; monitoring and fix-up strategies across team management components), and X (3.73/3.61/3.26; criteria of success across team management components). However, there was a relatively larger difference between the remaining two categories, i.e., VI and X.

We also briefly compared the results in this study on the use of SRL skills with the previous results in [1], in which SLP was conducted in a physical laboratory-based setting in the pre-COVID-19 pandemic. As shown in Figure 2, all average scores from both studies are above the 3.0 threshold line, and each category shows a similar average score. This would lead to a conclusion that both groups of students made reasonable use of SRL skills to carry out an SLP under the ongoing COVID-19 pandemic restrictions and in a year before the COVID-19 pandemic.

	20/FA		18/FA	
	Av.	**Std. Dev**	**Av.**	**Std. Dev**
C1	3.13	0.76	3.19	0.79
C2	3.59	0.61	3.43	0.67
C3	3.30	0.72	3.34	0.72
C4	3.25	0.76	3.28	0.80
C5	3.18	0.79	3.18	0.78
C6	3.27	0.79	3.16	0.76
C7	3.23	0.76	3.19	0.76
C8	3.43	0.71	3.35	0.73
C9	3.23	0.78	3.31	0.71
C10	3.54	0.66	3.46	0.67

(a) Average scores



(b) Plot of average scores

Figure 2. Comparison of category averages on Use of SRL Skills – 20/FA & 18/FA.

4. Conclusions and Significance

We have assessed the effectiveness of a GUI-based service-learning project utilizing two surveys. While the choice of a GUI-based SLP in 20/FA was inevitable under the COVID-19 pandemic, but it provided an opportunity to learn that students would have liked physical lab-based SLP activities more than this year's non-physical laboratory-based GUI development in a partially virtual environment. We noted, however, that both modes of project activities show no substantial difference in effectively facilitating SRL skills surveyed in this study. As the study in this paper was a case study, further research would bring more insights into the effectiveness of non-physical laboratory-based SLPs in improving student learning outcomes and the use of SRL skills for engineering freshmen.

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