International Journal of Engineering Education Vol. 34, No. 6, pp. 1897–1909, 2018
Printed in Great Britain
0949-149X/91 $3.00+0.00

Collaborative Instructional Models for Teaching Community Service to Engineering Students*

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This study aims to develop instructional models for service learning in engineering education and verify their effectiveness using a formative research methodology. Two types of instructional models were developed through literature review: (1) engineering design-based service learning and (2) instructional design-based service learning. This study examined the effects and improvements of instructional models for service learning by applying the models to the service-learning courses. Twenty-six students participated in fall 2015 and 64 in fall 2016. The following variables were measured to determine effectiveness: study time and study efforts for service learning, learning outcomes, learning satisfaction, student empathy, engineering design skills, satisfaction with community service activities, and volunteer motivation. Student reflection journals were analyzed to identify the strengths, weaknesses, and improvements of instructional models. The results of this study show that these instructional models help students guide service-learning activities and achieve their learning goals. Specific guidelines have been suggested for designing service-learning activities, taking into account the improvements that students have recommended.

Keywords: service learning; engineering design; community engagement; service activity; community service

1. Introduction

As the engineering profession emphasizes professional ethics, there is currently a growing interest in service learning in engineering education. Service learning can be defined as "a form of experiential education, in which students engage in activities that address human and community needs together with structured opportunities designed intentionally to promote student learning and development" [1]. Service learning has been shown to be effective in academic performance, motivation, teamwork, leadership, overall satisfaction, and preparation for work [2, 3]. Service learning in engineering education can be divided into two types: engineering design-based service learning and teaching-based service learning [4–6]. Students involved in the engineering design-based service learning meet with real clients in their local communities to identify their problems, generate solutions, and develop prototypes to solve them. Students involved in the teaching-based service learning work with team members to design interesting engineering activities and teach them to middle or high school students in their community. This study focuses on service-learning activities that integrate engineering design and community service activities. Most service-learning courses in the engineering field have been integrated into existing courses such as capstones, selective courses, and some first-year introduction to engineering courses [7]. Although there have been many attempts to provide students with service-learning experience in the engineering field, research is still lacking on instructional models that would provide guidelines for designing service-learning experiences. Therefore, the aim of this study is to develop two types of instructional models for engineering and instructional design-based service learning and evaluate their effectiveness on engineering design skills and service mindsets by applying them to service-learning courses.

2. Theoretical background

2.1 Characteristics of service learning

The term "service learning" has often been used to describe various types of experiential education, such as volunteer activities, community service, field education, and internship programs [7]. While various types of service programs can have educational benefits, service learning can be differentiated in terms of combining service activities with educational objectives. Both students and communities benefit equally from service-learning activities because services and learning are combined [1]. Howard suggested three key features of service learning: (1) it is a teaching methodology; (2) efforts are needed to integrate academic learning and related community service; and (3) there is an integration of experiential learning and academic learning [3]. Astin and his colleagues examined the effectiveness of service learning using longitudinal data from 22,000 students. They found that service-

* Accepted 12 June 2018.

learning activities had significant positive effects on academic performance, self-efficacy, leadership, choice of a service career, and plans to participate in service after college [8].

2.2 Service learning in engineering education

Globally, service learning has been adopted in a wide variety of disciplines within higher education. In the field of engineering education, service-learning opportunities are frequently provided to students. A representative example of a service-learning program in engineering is ''Engineering Projects in Community Service'' developed at Purdue University [4, 5]. This program creates partnerships between student teams and non-profit organizations from the local community. Students who participate in this service-learning program can do so between their first and senior year of study. Through this program, students acquire experience in solving a variety of real-world problems, ranging from designing learning centers for local museums to developing playgrounds for children with disabilities.

Service learning was incorporated into the first engineering classes at the University of San Diego [6]. There, first-year engineering students worked with economically disadvantaged and ethnically diverse students at a local middle school. The engineering students designed hands-on, fun, and educational engineering activities with their team members and implemented them with middle school students. The college students reported that the service-learning activities were worthwhile.

The College of Engineering at the University of Massachusetts Lowell has integrated service-learning projects into undergraduate core courses [9]. Service-learning projects have been conducted in public schools, museums, local municipalities, and various community organizations. For example, civil engineering students who took the ''Introduction to Engineering II'' course redesigned the parking lot of a local community health center for its new building. Electrical engineering students produced and distributed electronic devices to clients with disabilities. In this process, the students learned not only electrical theory, technology, and applications but also about the impact of such designs on the quality of life of individuals with special needs. Repeated surveys of students and faculty have shown that learning, teamwork, subject matter interest, and engineering motivation have all been improved with service learning.

Service learning at MIT started in 2001 as a joint enterprise of the MIT Public Service Center and the Edgerton Center, which is an interdisciplinary center that focuses on hands-on learning [4]. MIT offers service-learning experience to students through a variety of educational programs. The courses entitled ''Public Service Design Seminar'' and ''Freshman Advising Seminar'' teach technical subjects through service projects. In addition, many professors integrate service learning into their existing classes and encourage the implementation of service projects through competition.

The present study focuses on service-learning activities that support local communities by utilizing engineering design skills in the academic field of engineering. Particularly, this study developed instructional models to guide the processes of 1) improving living environments and developing auxiliary tools for socially disadvantaged people in the community using engineering design skills and 2) developing and implementing creative engineering educational activities for middle and high school students.

3. Instructional models for engineering service learning

3.1 Key elements of engineering service learning

This study presents the design and implementation of instructional models for service learning in the field of engineering education. Based on previous studies of service learning, the key elements of instructional models for service learning are service-learning experiences, community partners, motivation, a design thinking process, reflection, and a support system.

Service Learning Experiences: Service learning in engineering education primarily involves engineering design activities required by community organizations or teaching K-12 students what they have learned in their engineering classes [6, 9, 10]. The important consideration is to design service experiences that can achieve the learning objectives of the course through service-learning experiences. Note that service activities reflecting the needs of the community should be prepared in the classes. On the other hand, some service courses provide students with opportunities to volunteer [11]. Although those courses have educational benefits, these cases can be categorized as community service, according to Furco's terminology [1], as they aim to provide voluntary service activities rather than achieve academic learning objectives. Therefore, to provide students with effective service-learning experiences, instructors should design service-learning activities to provide community services while achieving the learning objectives of the course.

Community Partners: Building community partnerships is a fundamental aspect of the success of service-learning courses. Community partners of service-learning courses can be non-profit organizations such as those that work with socially disadvantaged groups, K-12 schools, and public organizations. To establish relationships with community organizations, the proposed service-learning activities and the community's role in those activities should be introduced in detail. Most community organizations are busy with their own activities, and thus they may initially be reluctant to participate as partners in service-learning courses. Therefore, it is important to emphasize the value of the service activity itself rather than focusing on the students' outcomes.

Motivation (Service Minds): Service-learning courses require more time and effort to prepare and operate than traditional lecture-based courses. Hammond reported on the relationship between the initial motivation of faculty to incorporate service learning and their subsequent satisfaction with such endeavors [9]. Factors motivating faculty participation in service-learning activities include the instructor's belief that service learning improves student learning outcomes, colleagues' respect, and faculty support [10]. The most significant deterrent to faculty involvement in service learning is the lack of recognition for such efforts in the faculty reward structure [11]. Externally motivating instructors to reflect on educational assessments or support, such as budgets or assistants, is also an effective way to encourage them to open service-learning courses. Motivation for the learner's service activities is also important so that students should have time to discuss and learn in advance about why service-learning activities are performed in the course and what benefits are gained from it.

Design Thinking Process: Service-learning experiences are designed to enable university students to become socially responsible citizens by making meaningful contributions to the community. This can be optimally achieved through the five-step empathize-define-ideate-prototype-test design thinking process, among various other methods that guide engineering design [12]. The design thinking process allows students to empathically understand situations, ideate solutions, and apply them to the community. It is also appropriate for identifying and solving real problems in the community [13].

Reflection: The most important element of service learning is reflection. The educational benefits of service-learning activities can be effectively realized through reflection activities that link the service-learning experience to the learning objectives [14]. It is important to include reflection activities in service learning and to share the results of such reflection with colleagues. The following guidelines provide faculty with a set of criteria for designing and evaluating the reflective activities for a particular course [15].

(a) Effective reflection activities link experience to learning.
(b) Effective reflection activities are guided.
(c) Effective reflection activities occur regularly.
(d) Effective reflection activities allow feedback and assessment.
(e) Effective reflection activities foster the exploration and clarification of values.

Support System: Staff or organizational support is necessary to find community organizations that fit the characteristics of the course and are willing to cooperate as effective partners in service-learning activities. Most universities that encourage the integration of service activities into existing courses have a service-learning support organization with a budget for students' service-learning activities. In addition, a web-based support system is required to guide the learners' service activities. It is desirable that external community partners who cooperate in service-learning activities be able to utilize the learning management systems commonly used in universities. If external organizations find it difficult to use such learning management systems, there may be limits in the community partners' abilities to observe the learners' activities or provide appropriate feedback.

3.2 Specification of instructional models

Effective service learning for engineering students should be designed not only for teaching and learning activities but also for building partnerships with community members and providing physical and emotional support. The instructional models for service learning aim to systematically provide engineering students with the opportunity to apply the engineering design skills learned in their design courses to help socially disadvantaged people in the community. The participants should act, as shown in Fig. 1, to meet community needs and provide an effective service-learning experience that is appropriate for engineering students.

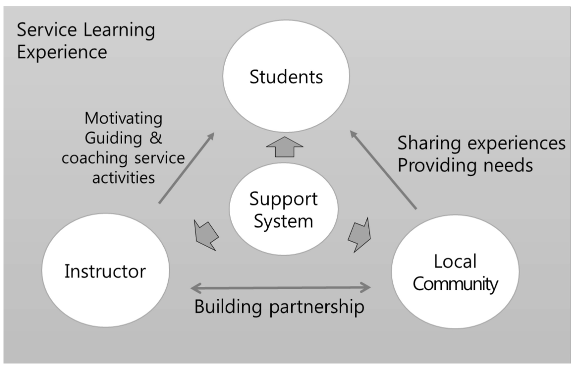

Fig. 1. Participants' Roles for Service Learning.

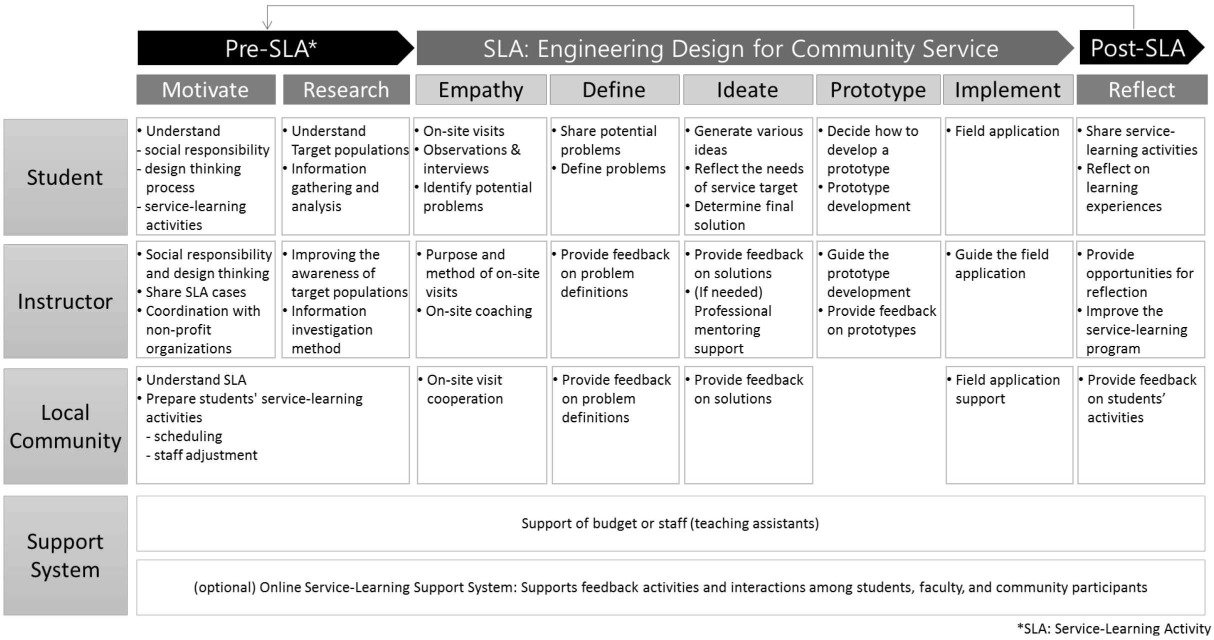

Fig. 2. Instructional Model for Engineering Design-based Service Learning (hereafter EDBSL).

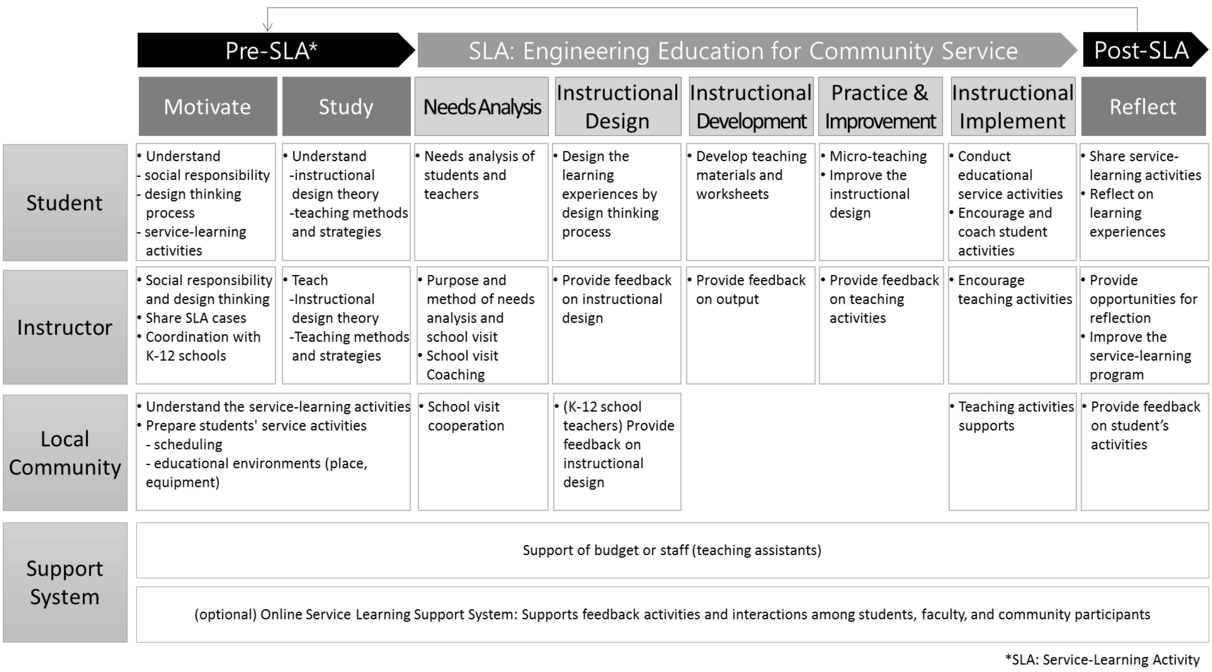

Fig. 3. Instructional Model for Engineering Education-based Service Learning (hereafter EEBSL).

As mentioned in Section 2.2, service learning in engineering education consists mainly of service activities based on engineering design or engineering education. Fig. 2 presents the instructional model for a service-learning program based on engineering design, and Fig. 3 shows the instructional model for a service-learning program based on teaching. The two instructional models consist of preparation activities, service-learning activities, and post-activity stages, as well as suggested activities that the learner, professor, community, and support system should perform in a step-by-step format.

4. Research methods

A formative research methodology, a type of developmental research intended to improve design theory for designing instructional practices or processes, was applied to evaluate the effectiveness and

Table 1. Research Participants

Semester	EDBSL	EEBSL	Total
Fall 2015	20 (M: 19 F: 1)	6 (M: 4 F: 2)	26 (M: 23 F: 3)
Fall 2016	31 (M: 23 F: 8)	33 (M: 22 F: 11)	64 (M: 45 F: 19)

EDBSL: Engineering Design-based Service Learning. EEBSL: Instructional Design-based Service Learning.

improvement of instructional models for service learning in engineering education [16]. The strengths, weaknesses, and improvements of these models were examined by applying the models to the service-learning courses. The opinions of the students who completed the service-learning courses were then analyzed.

4.1 Participants

The participants were mostly engineering students who completed the core course of the "Project for Sharing" at University A. This course is a service-learning course developed according to the instructional models proposed in this study. The study participants are listed in Table 1. In the fall of 2015, several students participated in engineering education-based service-learning activities. Therefore, the instructional models were applied for two years to determine the effects and develop improvements.

4.2 Procedures and instruments

According to the service-learning instructional models, a partnership was established with community organizations that could collaborate on the service-learning activities before opening the service-learning course. After 15 weeks of service-learning activities were completed according to the instructional models, the following variables were measured to determine the effectiveness and identify improvements: study time and study efforts for service learning, learning outcomes, learning satisfaction, student empathy, engineering design skills, satisfaction with community service activities, and volunteer motivation. In addition, all participants were asked to write a reflective journal on the service-learning activities. Learning outcomes and learning satisfaction were measured to confirm the general learning effects of the course. To determine the effectiveness of the service-learning activities, we measured student empathy, engineering design skills, satisfaction with community service activities, and volunteer motivation. A detailed description of the research instruments is presented in Table 2. The learning outcomes scale, developed based on Eom et al.'s study [17], required the students to evaluate their own achievements in the current service-learning course. The scales for learning satisfaction were developed by referring to AR Baugh's [18] study. An empathy scale was developed with reference to items proposed by Davis [19]. The scales for assessing the engineering design skills were developed based on a performance-based evaluation rubric for evaluating the engineering design skills suggested by Jin et al. [20]. A satisfaction scale for the community service activities was developed by referring to the items developed by Silverberg et al. [21]. The volunteer motivation for participation was selected based on the characteristics of service-learning activities among the volun-

Table 2. Research Instruments

Measures	Scale Details
Study time per week	Five alternatives (less than 3 hours per week [1] and more than 12 hours per week [5]).
Study efforts	Five-point Likert-type scale (from extremely low to extremely high) [23].
Learning outcomes	Four items (a = 0.89). Sample item: I feel that I learn more in this course than in other courses.
Learning satisfaction	Three items (a = 0.91). Sample item: I would recommend this course to others.
Empathy	Three perspective-taking, two empathic concern, and two personal distress items (a = 0.81). Sample item: I sincerely tried to understand the socially disadvantaged people that I met in this course.
Eng. design skills	Eight items (a = 0.93). Sample item: I can explore and discover a challenging and influential problem.
Service activity satisfaction	Seven items (a = 0.86). Sample item: I have had a new experience through community service activities in this course.
Volunteer motivation	Three items (a = 0.92). Sample item: I think that I should participate in volunteer activities through the community service opportunities provided by this course.

teer motivation scale proposed by Cnaan and Goldberg-Glen [22].

To qualitatively analyze the educational effectiveness and improvements of the educational program developed by applying the instructional models, the participants were asked to write a reflection journal after completing the service-learning activities. The students were asked to write their opinions and thoughts on the three structured questions presented in the reflective journal. The three questions were the following: (1) Write down three keywords to describe your service-learning activities. (2) What did you learn and feel from the service-learning activities? (3) What do you think could be improved regarding the service-learning activities? The validity of all test items and the reflective journal were examined by two experts with Ph.D.'s in educational technology.

4.3 Analysis

Basic statistical analyses were performed on all test items including the study time and study efforts for service learning, learning outcomes, learning satisfaction, engineering design skills, satisfaction with community service activities, volunteer motivation, and student empathy. The learners' opinions expressed in the reflective journals were analyzed using a content analysis method [24]. Two educational technologists participated in this content analysis. Each response was reviewed on a line-by-line basis, and the units of meaning were identified. The units consisted of words, phrases, and/or sentences that contained meaningful information about the learner's thoughts regarding the service-learning activities. The units were coded and grouped. The results of the content analysis were cross-checked for validity by two experts. A cross-validation check revealed 0.92 proportional agreement between the analysts. Disagreements were resolved through discussion. Furthermore, a frequency analysis was conducted to compare the learners' responses based on the units analyzed among the groups.

5. Results

5.1 Implementation of engineering service learning

The service-learning course was implemented in the engineering curriculum by applying the instructional models from the fall semester of 2015. The present study is based on the results of operations in the fall semesters of 2015 and 2016. For *engineering design-based service activities*, partnerships were established with local organizations for socially disadvantaged people, such as rehabilitation centers for blind people, nursing homes for severely disabled people, and special-education schools. Before the service-learning activity, the students discussed the social responsibilities of engineers. Students who completed the same course in the previous semester visited the classroom to introduce their activities and share what they learned and felt from the service activities. Through these activities, students were motivated to think about why service activities for the underprivileged are necessary. Afterwards, the students selected the subjects of the service activities, formed teams, and conducted information investigations on the subjects. In other words, the team that worked with elementary school students with visual impairments investigated the inconvenience of their daily lives, assistive products for the blind, and patents.

To analyze the needs through on-site visits, we developed observational perspectives, methods, and interview questions and communicated them to the people in charge of the community partner organizations. The students also observed poor living conditions and shared their empathy with the people and the difficulties they experienced. Students shared the problems that they identified through on-site visits with their team members, identified problems to be solved, sent proposals for problem-solving to the people in charge of the community organizations, received feedback, and revised the plans accordingly. Students devised various ideas to solve the selected problems and selected the most realistic and feasible solutions. They also received feedback from their local community partners regarding the solution. Then, prototypes were developed, tested, and delivered in the field. Finally, students shared what they learned, feelings, and commitments to improve the situation through the final presentation. Examples of engineering-based service-learning activities are shown in Fig. 4.

For *engineering education-based service activities*, it was decided to establish a partnership with middle schools located in the community. The teachers in charge of the service activities understood their roles and promised to support the students' service-learning activities. Like the students who participated in the engineering-based service activities, the students understood the social responsibilities of engineers and performed awareness activities concerning socially disadvantaged groups. Students were instructed to set learning objectives through discussions with students who had completed service-learning activities the previous semester. The students were trained to develop educational programs by applying the design thinking process and instructional design theory. Prior to developing an educational program, students investigated the middle school students' understanding of appropriate technology, design thinking, and socially dis-

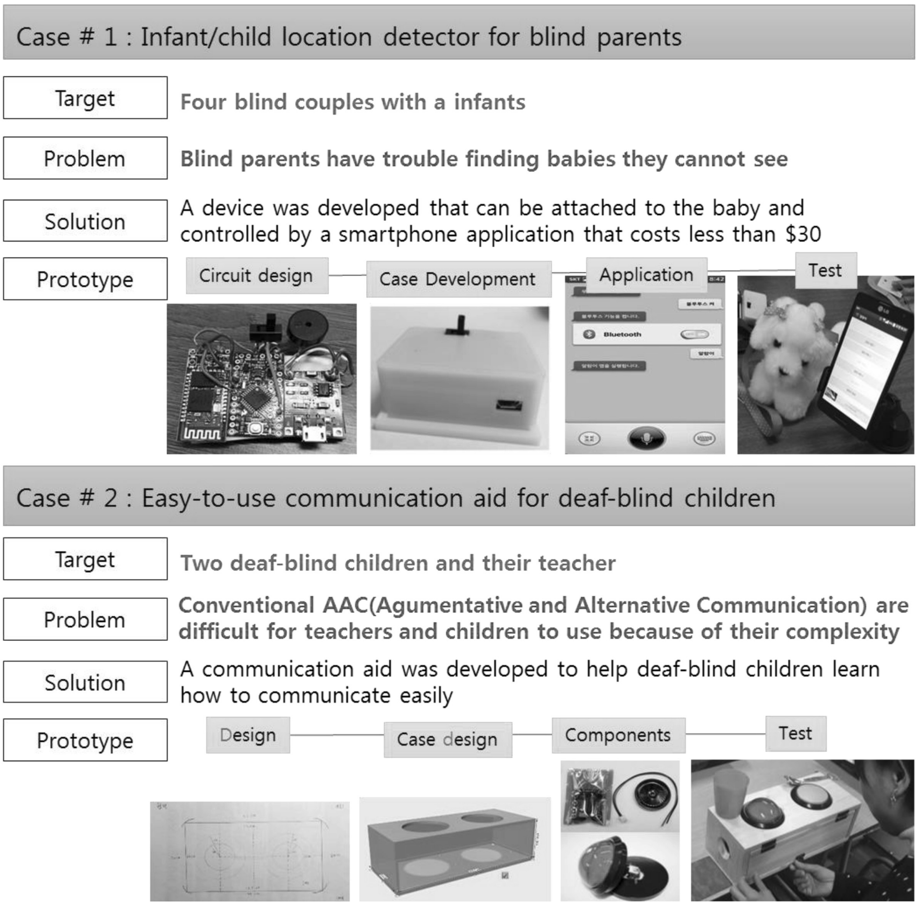

Fig. 4. Examples of Engineering Design-based Service Activities.

advantaged people and their educational needs. The students designed a creative problem-solving education program to improve the life quality of the socially disadvantaged and received feedback from the middle school teachers. Students developed teaching materials and worksheets. After the students had practiced the teaching activities, they went to the middle school and conducted educational and coaching activities. The middle school students were asked to evaluate the educational activities of college students with a five-point Likert-type scale on satisfaction items. Last, the students shared their learning, feelings, and commitments through a final presentation. Through the educational activities of the college students, the middle school students proposed the idea to develop glasses that provide subtitles during musicals or theatre performances for deaf people or to develop a stick with a rear sensor to help the visually impaired.

5.2 The effects of service-learning activities

The time the students spent completing service-learning activities generally ranged from 3–9 hours; 3–4 hours was required for the instructional design-based service learning and 7–8 hours were needed for the engineering design-based service learning. The results showed that the students put more efforts into the service-learning activities than average. The students rated highly on all variables related to educational effectiveness. Students in the EDBSL class showed higher learning outcomes, empathy, and volunteer motivation than those in the EEBSL class, as more time and efforts were dedicated to the service-learning activities. On the other hand, the learning satisfaction and satisfaction with service activities were higher in the EEBSL class than in the EDBSL class. The causes and improvements were confirmed by analyzing the students' reflective journals. These results showed that the service-learning programs based on the instructional models had positive effects on learning outcomes, learning satisfaction, and service activity satisfaction. In addition, they were found to enhance student's empathy, engineering design skills, and volunteer motivation. To improve student learning satisfaction, however, the students in the EDBSL class should be guided more closely in identifying problems and solutions that match their competence level; moreover,

Table 3. Descriptive statistics of the dependent variables on the service-learning effectiveness

Measures	Fall 2015 EDBSL $n = 20$ M (SD)	Fall 2015 EEBSL $n = 6$ M (SD)	Fall 2016 EDBSL $n = 31$ M (SD)	Fall 2016 EEBSL $n = 33$ M (SD)
Study time per week[a]	3.58 (1.12)	2.12 (0.93)	3.88 (1.23)	2.34 (0.87)
Study efforts	4.03 (0.82)	3.66 (0.81)	4.26 (0.93)	3.76 (0.88)
Learning outcomes	4.08 (0.65)	3.96 (0.82)	4.20 (0.65)	4.02 (0.54)
Learning satisfaction	3.97 (0.92)	4.56 (0.40)	4.42 (0.50)	4.78 (0.79)
Empathy	4.36 (0.80)	4.28 (0.74)	4.48 (0.71)	4.36 (0.64)
Eng. design skills	4.04 (0.66)	4.02 (0.75)	4.12 (0.77)	4.09 (0.64)
Service activity satisfaction	3.77 (0.81)	4.44 (0.54)	4.09 (0.66)	4.65 (0.67)
Volunteer motivation	3.92 (0.72)	3.64 (0.99)	4.01 (0.81)	3.64 (1.04)

a. 1. Less than 3 hours; 2. 3–6 hours; 3. 6–9 hours; 4. 9–12 hours; 5. Over 12 hours.

appropriate support in each service activity phase should be provided.

5.3 Results of the analysis of student reflective journals

As shown in Table 4, the keywords that students suggested for service-learning activities were similar for both the EDBSL and EEBSL classes. The types of service-learning activities were different, but what the students learned and felt in the process and the results of their activities were similar. Students in the EDBSL class designed and developed prototypes to assist the visually impaired and severely handicapped in their daily lives. As a result, they encountered a range of unexpected problems during the design process and prototype development, so they expressed emotions, such as frustration, sadness, and regret. For this reason, it was interpreted that student learning satisfaction and service activity satisfaction was lower in the EDBSL class than in the EEBSL class. Students in the EDBSL class presented "teamwork," "ideas," and "output" as keywords in their activities that yielded real output through team-based engineering design activities. On the other hand, the EEBSL class students suggested "design thinking" and "improvement of awareness for the disadvantaged," which were emphasized in the teaching activities. Other keywords included "professors," who brought their enthusiasm and passion to the course, and "community."

What students learned from the service-learning activities and how they felt were also similar in the two groups. The students' opinions were categorized as understanding of socially disadvantaged people, importance of service activities, engineering

Table 4. Frequency analysis for keywords on service-learning activities

		EDBSL Fall 2015 $n = 20$	EDBSL Fall 2016 $n = 31$	EEBSL Fall 2015 $n = 6$	EEBSL Fall 2016 $n = 33$
Target	Socially disadvantaged people (disabled)	2	6	2	11
	Middle school students			1	7
Process	Collaboration/team	10	13		5
	Empathy/interest/love/care	9	7	3	11
	Difficulty/trial efforts		5		
	Engineering	2	4		2
	Ideas/creativity		6		1
	Design thinking			1	7
	Real problem				3
Output	Outputs	5	6		1
Outcome	Sharing/give	16	19	2	20
	(Educational) volunteer	5	9	2	12
	Life improvement	3	1		
	Improved awareness			2	5
	Regrettable/sad	2	1		
	Worthwhile/proud	2	9		7
	New experience		3		1
	Others	1	1	2	3
	Total	57	90	15	96

Table 5. Frequency analysis on students' opinions on the learning and feeling through service-learning activities

		EDBSL		EEBSL	
Category	**Opinions**	**Fall 2015** *n* = 20	**Fall 2016** *n* = 31	**Fall 2015** *n* = 6	**Fall 2016** *n* = 33
Socially disadvantaged	Understanding of socially disadvantaged	6	12	2	17
	Poor living standards of socially disadvantaged people	1	4	2	5
Service activity	Importance of sharing/need for service	5	11	2	7
	Many people involved in shared activities		3		2
	Being able to help others		2	2	1
	Rewarding/value of service activities	3	10	1	9
	Motivation for volunteering	5	4	2	3
	Sharing through engineering		5	1	
Engineering design activity	Engineering design skills	2	4		
	CAD/3D modelling	1	1		
	Difficulty in defining problems		2		2
	Difficulty in solving real problems	1	5		
Teaching activity	Teaching competence				6
	Effects of design thinking process			1	7
	Difficulty in teaching activities			1	3
	Reward of teaching activities			1	6
	Outstanding ability of students				8
Teamwork	Satisfaction of team project completion	1	4	1	
	Communication with team members	1	3	1	2
	Difficulty of teamwork activities	1	1		
	Teamwork skills	3	12		5
	Collaboration skills		7		
	Total	30	90	17	83

design activities, teaching activities, and teamwork. Students in the EDBSL class improved their engineering design ability in the process of identifying and solving real problems for socially disadvantaged people, while there were students who felt that it was difficult to apply the theoretical knowledge in practice. The students in the EEBSL class felt the need to improve their teaching competence and felt rewarded for their teaching activities, while some students had difficulty when their teaching activities that did not go as planned. The students developed their teamwork skills in the process of conducting team-based service-learning activities.

The following are some of the students' opinions.

> "The process of meeting the blind, listening to their stories, and understanding their difficulties was a new experience for me. I conducted observations and interviews with team members to identify the inconveniences of the visually impaired. But we had difficulty finding a valuable problem that could solve their difficulties, because blind people had many institutional, environmental, and social problems that we could not solve. As a result, I worked with team members to carry out a cane improvement activity that we could solve and felt that our teamwork skills were improved as well."
>
> Student A in the EDBSL class

> "At first, I was annoyed about having to leave school and teach students. However, I improved my awareness of socially disadvantaged people through these lessons, and I felt motivated to teach middle school students about this. Accordingly, the four weeks I spent with the students seemed too short, and I felt very rewarded by my teaching activities. I learned that my abilities, not money or materials, can help others, and I would like to participate in service-learning activities again in the future if I have the opportunity."
>
> Student B in the EEBSL class

In the fall of 2015, which was the first time service learning was conducted according to the two different instructional models, many improvements were proposed by the students. The instructor initially assigned a target for the service activity of each team, and in the fall of 2016, the students were allowed to select their own target for their service-learning activity by arranging the community schedule in advance according to class time. In the fall of 2015, the students relied on information-gathering activities to understand the socially disadvantaged groups that they would be working with. In the fall of 2016, lectures were offered to enhance their understanding of the socially disadvantaged. In the case of the EDBSL class, a team mentor (a professor in the field) was assigned to each team, and students had time to explain the project execution process they performed every two weeks and receive feedback. However, the feedback from the mentor was not very helpful, so students were not satisfied with having a mentor. Mentors did not have a deep understanding of the situation or needs of the socially disadvantaged, so they often suggested technologies that did not fit students' goals or

Table 6. Frequency analysis of students' opinions on the improvements for service-learning activities

		EDBSL		EEBSL	
	Improvements	**Fall 2015** *n* **= 20**	**Fall 2016** *n* **= 31**	**Fall 2015** *n* **= 6**	**Fall 2016** *n* **= 33**
Subject	Increasing opportunities to understand the target populations	5	1	1	
	Opportunity to investigate the opinions of middle school students			1	
	Allow student selection of partner community organization	1		1	
Process	Community visits should be conducted during class time	3			
	Provide systematic guidelines	1			
	Expansion of idea implementation time	3	2		
	Improve the mentoring method	5	–		–
	Design activities during class time	6			
	Difficulty in securing a design space	1	1		
	Difficulties in participating in lectures and concurrent design activities	1			
	Guide on how to develop a prototype	1			
	Contents adjustment			2	
	Guide coaching methods			2	1
	Increase design and activity costs		2		
Teamwork	Provide a way for all students to work hard	3	1		1
	Individual project notes were ineffective	2	–		–
	Total	32	7	7	2

that students could not implement. As a result, the next time, professional mentoring was provided only when requested. To reflect the students' opinion that instructors should provide systematic lectures and specific guidance, the lecture and design activities were planned to be carried out within the designated class time. In the case of the EEBSL class, the learning activities were adjusted for the eight-hour educational program, and the strategy for coaching the middle school students' learning activities was conducted as an additional lecture. Although this course uses a pass/fail assessment method, individual project notes were introduced so that all students could participate well, but this was ineffective. Therefore, two peer evaluations were conducted during the 2016 semester. These improvements reduced the amount of negative student feedback in the 2016 school year from the 2015 school year.

The following are some of the students' opinions.

> "Our team spent a lot of time developing assistive devices for visually impaired parents to help them know where their baby was when they wanted to know. Every second week, we explained the process that we had been following to a professor in the department of Information and Communication, who was a mentor, and received feedback, but the feedback was not helpful. We might have been able to finish the project sooner if we had focused instead on the design activities at that time."
>
> Student B in the EDBSL class

> "I visited the "Bright Mind" institution, a nursing home for severely handicapped people, and conducted observations and interviews according to the plan. But I was scared when I first met them, so I did not know what to do. Simply investigating information on the Internet was not enough to understand them. It was very meaningful to meet the people with disabilities in person, but it was difficult to work with team members outside of class time. Community visits should be rescheduled to be done in class time."
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> Student C in the EDBSL class

6. Discussion

6.1 Effectiveness of the instructional models for service learning

The purpose of this study was to develop instructional models to guide and support customized service-learning activities for engineering students and to verify their learning effectiveness. The learning objective of the service-learning activities was to enhance the students' awareness of socially disadvantaged people by engaging in service activities and applying their engineering knowledge and skills. The instructional models proposed in this study were found to be effective in helping students achieve their learning objectives and enhance their empathy, engineering design skills, and volunteer motivation.

First, the students spent 3 to 12 hours per week participating in service-learning activities, and their efforts to learn were also high. In general, in the case of service activities in engineering education that have been used previously, students visit the community to work with children with disabilities or with children in daycare centers to help them with the challenges of daily life. These volunteer activities helped improve the students' understanding of the underprivileged, but some found it difficult to apply their engineering knowledge and skills to these situations. On the other hand, the service-learning education program described in this study provided the students with the opportunity to simultaneously perform service activities while solving real problems and confirmed that a similar learning time and effort to other major courses were required.

Second, the results showed that the learning outcomes and student satisfaction levels were higher than average; moreover, the improvement in engineering design ability was also higher. This was confirmed by both the evaluation using the research instruments with a 5-point Likert-type scale and the reflection journals written by the students. The results of the quantitative evaluation using the research instruments are listed in Table 3, and the qualitative evaluation results of the reflection journals are presented in Tables 4 and 5.

In the case of the EDBSL class, the students were expected to observe and interview socially disadvantaged people, identify problems, solutions, and prototypes for the inconveniences of their lives, and deliver the results directly to the people themselves. However, they had difficulties when faced with various unexpected problems during the process. As a result, students in the EDBSL class reported lower levels of satisfaction than the EEBSL class, but it was found that their academic achievement level was higher because of the sense of accomplishment involved in overcoming difficulties and achieving goals. This can be confirmed by comments made in the reflective journals. Table 4 shows that feelings of frustration and sadness were expressed by students in the EDBSL class only in terms of the process and outcome.

In the case of the EEBSL class, the engineering students had no confidence in their teaching abilities at the beginning. In the process of developing and practicing educational programs, it was confirmed that middle school students participated well in learning activities and displayed excellent learning outcomes, which made the teaching activities of the college students rewarding. Table 4 presents the student feedback on the service-learning activities. Many students expressed feelings of reward and joy in sharing activities and awareness of the challenges faced for disadvantaged groups. Students in the EDBSL class responded that they had learned engineering design skills, whereas students in the EEBSL class responded that they had learned teaching strategies.

Third, the team project based on real-world problems helped the students improve their empathy, volunteer motivation, and communication and teamwork skills, which are key 21st-century skills. The first-year students learned about the engineering design process through the activities of generating conceptual ideas from the problems of daily necessities in the introductory course of engineering design. Service-learning activities improved teamwork and communication skills by solving real-world problems with real clients utilizing engineering design skills learned in the introductory design course. The students participated in design activities to help socially disadvantaged people, so it was confirmed that the service-learning activities enhanced the students' empathy and volunteer motivation.

6.2 Specific guidelines for designing service-learning activities

After the improvements proposed by the students who participated in fall 2015, the instructional guidelines for designing service-learning activities were revised. These include the following. First, prior arrangements must be reached on the specific schedules for service-learning activities as well as a consensus on each role in establishing partnerships with the community organizations, with whom students will cooperate in the pre-SLA phase. Building relationships with institutions that are responsible for service activities rather than with individuals who are socially underprivileged in the community is optimal. This is because, when conducting service activities by directly contacting individuals, there may be unexpected situations, such as increasing requirements or scheduled meetings not being honored. Therefore, students may have difficulty in carrying out service activities. In addition, if the schedule is set according to the process of the service activity, it is difficult to meet the schedule of the service activities because there are separate schedules for each community organization. Therefore, it is a way to support the students' service-learning activities in good faith by establishing a preliminary schedule and striving to keep it.

Second, providing students with the opportunity to select the target populations for service-learning activities makes them more focused on service activities. As students take on these courses, they develop personal goals and specific service activities that they want to do. Therefore, it was confirmed that it is educationally meaningful for instructors to select the students' preferred subjects and institutions rather than to arbitrarily match them.

Third, students who are participating in service-learning activities for the first time may experience fear and anxiety. To assist them, it would be helpful to paint a clear picture of the entire service-learning activity and provide specific step-by-step instructions. Providing guidance on individual performance in service activities and feedback for team activities every week for 20–30 minutes is optimal. Furthermore, most of the team project activities should be performed during class time to ease student collaboration.

Fourth, when conceptual ideas are derived, students should be guided on how to implement them as concrete objects in the engineering design class. Most students purchase materials themselves to implement the conceptual solutions, but there are also cases where it is difficult for students to develop these themselves. The students required assistance from technicians, but it was difficult for them to find out where they could obtain such help. Instructors should have information on this in advance to guide the students. Of course, this would not be a problem if there were learning factories in the university.

Fifth, communication can be made more efficient by establishing an online community where students can communicate directly with the local partner institutions. The use of social media sites or a webpage for the service-learning course would provide an effective platform for communication.

6.3 Limitations

The effects of the instructional models proposed in this study were analyzed only according to the opinions of the learners. Therefore, future research should also take into account the opinions and experiences of the instructors and community members involved in the service-learning activities.

7. Conclusions

Two types of service learning teaching models for engineering students were found to have a positive effect on learners' learning outcomes and learning satisfaction. While community service involves a lot of time and effort, it has been found to have a positive impact on engineering design ability, empathy, and volunteer motivation. In particular, while working with team members to solve real-world problems, students faced many practical challenges that normally do not arise with engineering designs, which are performed only in the classroom. Through the experience of overcoming these difficulties, learners were able to enhance communication, teamwork, and practical problem-solving skills. Through feedback from students, it was found learners were more motivated and successful in service-learning projects if they were able to select their preferred service activity, method, and partner. Therefore, for future service-learning courses, the instructor in charge should limit his or her role to monitoring and facilitating the students' activities.

Acknowledgements—This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2017R1D1A1B03035503).

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