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Learning by teaching: undergraduate engineering students improving a community's response capability to an early warning system

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This paper reports on a project in which students designed, constructed and tested a model of an existing early warning system with simulation of debris flow in a context of a landslide. Students also assessed rural community members' knowledge of this system and subsequently taught them to estimate the time needed for evacuation of the community in the event of a landslide. Participants were four undergraduate students in a civil engineering programme at a university in Thailand, as well as nine community members and three external evaluators. Results illustrate project and problem-based, experiential learning and highlight the real-world applications and development of knowledge and of hard and soft skills. The discussion raises issues of scalability and feasibility for implementation of these types of projects in large undergraduate engineering classes.

Keywords: problem-based learning; project organized learning; engineering education; higher education; hands-on-experience

1. Introduction

The titles of recent publications in the field of engineering education offer evidence of a growing interest in engaging students in new approaches to learning. These include but are not limited to immersive learning (Jaeger et al. 2013), problem-based learning (PBL) (Wittig 2013), collaborative learning, online learning (Lawton et al. 2012), cooperative learning (Mourtos 1997), etc. One of the less common yet more innovative approaches involves providing students with opportunities to learn in real contexts beyond the classroom and laboratory settings. The value of learning in real contexts relates to the fact that some concepts (e.g. sustainable solutions and decision-making) may be difficult to teach in a classroom or laboratory setting (Wittig 2013).

Furthermore, given that engineering education aims to prepare students to actually serve as practitioners in the profession (Feisel and Rosa 2005), it is imperative that the students be given opportunities to actively practice as part of their learning, to engage in the engineering profession (Olds et al. 2012) and to handle what Ferro et al. (2003) refer to as real data and real equipment. Some of these real-life approaches involve pedagogies of engagement (Smith et al. 2005) that

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allow students to conduct research (see Olds et al. 2012) and to teach. Real-life approaches can also enable future engineers to learn soft skills related to communication and interpersonal interactions (Balaji and Somashekar 2009), decision-making, conflict resolution, etc.

The project presented in this paper provided an opportunity for undergraduate engineering students to help community members learn certain basic skills and knowledge that can ultimately save lives. In this project, students pre-tested community members' basic mathematics' skills, designed, built and tested a model of an existing community early warning system and subsequently used a simulation of a landslide to teach community members how to estimate the time needed for evacuation of the community in the event of a landslide.

The project took place in Thailand where, from 1970 to 2006, approximately 534 people have died as a result of landslides (Soralump 2007). While this project focused only on landslides, its results are relevant and significant in other contexts where communities face threats from natural disasters be they in the form of tsunamis, hurricanes, floods, etc. It is particularly relevant in contexts where communities depend on early warning systems to alert community members to evacuate before the disaster strikes. An early warning system can be defined as follows:

> The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss. (IFRC 2012, 7)

Early warning systems are becoming increasingly common. In fact, 'Early warning is a global political and legal imperative' (IFRC 2012, 18). They are also becoming increasingly complex. While their complexity allows them to deal with many data and factors simultaneously, it can also make them less user-friendly to the members of the communities in which they are installed and, therefore, less effective. In a review of the literature of prediction times for early warning systems for landslides, Busslinger (2009) summarised four features of such a system as follows: risk knowledge, monitoring and warning service, dissemination and communication, and response capability.

The category of response capability refers to the local community capacity to react and respond to the system. Improving response capability involves ensuring that such systems are 'people-centred' and understandable to populations they are designed to warn (ISDR 2007). This need to make early warning systems understandable may be particularly acute in communities where members may have lower levels of education.

The project reported on in this paper describes an initiative in which engineering students helped improve community members' response capability to an early warning system. In doing so, the students had an opportunity to gain knowledge about early warning systems and learn about how users interact with such systems. This knowledge can be gained in the classroom and laboratory settings yet it is in a real context that students benefit from a more systemic and comprehensive understanding. It is also in a real-life context with real-life problems that students can gain an appreciation and respect for the implications of the profession and its impact on people's lives. In such projects, students gain soft skills that may make them more employable upon graduation. They also learn to deal with complex, ill-structured problems that cannot always be studied in didactic settings.

1.1. *Purpose and process*

The purpose of the project reported on in this paper was to provide undergraduate engineering students with an opportunity to solve an actual problem in a real engineering context. The project involved a team of four engineering students along with a principal investigator (PI) modelling and simulating an early warning system for landslides and teaching community members about the system and about the response time needed for evacuation. To achieve this purpose, the project was conducted in six phases as follows:

(1) Students collected on-site data about the early warning system for landslides (EWSLS).
(2) Students assessed (a) community members' understanding of the system and (b) their basic math skills.
(3) Students created a model of the system with simulation of a landslide with debris flow.
(4) Students created information and activity sheets to teach community members about the EWSLS.
(5) External experts conducted an evaluation of the model, simulation and teaching techniques and sheets from Phase 4.
(6) Students taught community members about the system and assessed community members' understanding of the system and their satisfaction with the teaching.

The next section of the paper outlines the theoretical framework that formed the foundation of the study. The subsequent section provides background on the early warning system that was created by a Japanese company and used as part of the project. The methods outline the selection of student and community participants, the process involved in the design of the model and of the simulation of the landslide, the expert evaluation, and the community teaching and assessment process. Results are presented according to these six phases. The discussion and conclusion highlight issues of scalability and feasibility of these types of projects for students in other contexts of engineering education. Also discussed are issues pertaining to assessment of students in these types of project- and problem-based, real-world learning.

2. Theoretical framework

The foundation that underpins this project draws on multiple theoretical perspectives, the most important of which is that of constructivism. A constructivist perspective applied to learning emphasises a shift from the teacher who transmits knowledge to passive learners, for example, using lectures, to an approach that actively engages learners in constructing knowledge. Knowledge-building versus transmission, meaning-making versus reproduction of knowledge, collaboration, and authentic, relevant learning are privileged in this approach (Jonassen 1991, 1994). Learning thus becomes embedded in social experience (Honebein 1996) and the social experience is one that is highly contextualised.

This approach is particularly relevant for learners in professional schools who will eventually practice as, for example, engineers, doctors, lawyers, teachers, nurses, etc. According to this approach, 'activities are grounded or situated in the very practice in which the learning will be applied. They relate directly to the practice, inform and are informed by it' (Murphy 2003, Conceptual framework section, para. 3)

This practical context of use represents an authentic, real-world application of knowledge that takes into account the complexity involved in the natural environment and in which students are solving real-world problems as opposed to merely dealing with abstracted knowledge (Jonassen 1991, 1994, 1996). Learning is embedded in an authentic problem-solving context instead of in an academic context (Wilson and Cole 1991). Such a context becomes one in which 'the traditional distinction between working and learning is transcended' (Lester 1995, 51). It is a context in which learners become practitioners who must grapple with real problems of practice that are 'messy, indeterminate' and that require 'a kind of improvisation, inventing and testing' (Schön 1987, 4–5).

Having students grapple with real-world problems involves engaging them in PBL approaches. PBL (see Savery 2006) refers to learning that is collaboratively self-directed by students and for which they have responsibility and which focuses on ill-structured, real-world problems. Thus, problems are not didactic and do not focus on discrete subjects (Savin-Baden 2000). Such problem-solving can take place by engaging students in projects. The value in working on projects lies in the holistic nature of this type of learning and the multitude of skills that come into play. Project-based learning is also referred to using Dewey's (1938, 1997) term of *learning by doing*. It is an approach frequently relied on in engineering education (see Palmer and Hall 2011; Gavin 2011; Hall, Palmer, and Bennett 2012). Palmer and Hall (2011) reviewed and summarised the essential attributes of this inductive approach noting that it involves team work, problem-solving and/or task completion, multi-disciplinary activity carried out over a period of time, creation of an artefact and final product, with the teacher in the role of advisor or facilitator.

Constructivist, problem and project-based learning are also linked to a form of learning referred to as experiential that involves real-world applications and development of knowledge and skills. Although experiential learning can adopt many forms and occur in a variety of contexts, it will always include real-life meaningful, authentic as opposed to didactic activities (Chan 2012a). Such experiences allow students to 'interact with the local community to observe their needs and reflect on social issues' (Chan 2012a, 407). Experiential learning in engineering education might take on the form of community service involving students engaged in problem-solving and thinking critically through participation in reconstruction activities following an earthquake (Chan 2012b, 2012c).

Unfortunately, experiential learning rarely figures as part of engineering curricula because, as Chan (2012b, 2012c) explained, unlike in a traditional classroom, academics may be unfamiliar with the processes associated with this type of learning, may question the predictability and validity of its outcomes and, furthermore, may be unaware of how to assess its outcomes.

In spite of these challenges, a constructivist approach to engineering education involving problem-solving through practical projects in a community setting provides an opportunity for students to learn hard and soft skills that might not be easily acquired in a classroom or laboratory setting. Furthermore, not only do students gain real-life professional experiences that can make

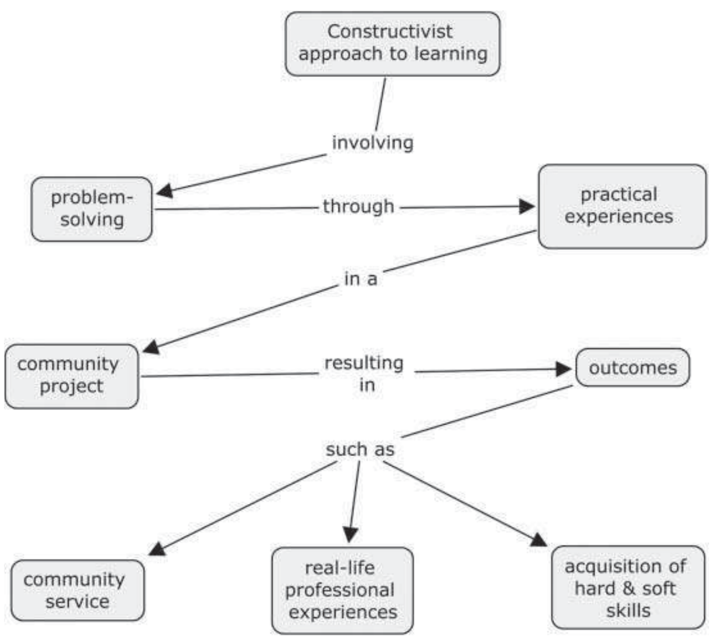

Figure 1. Concept map of the approach underpinning the study.

them more employable upon graduation, they also gain an opportunity to apply their skills and knowledge to help communities. Figure 1 summarises the benefits of learning using this approach.

3. Background on the early warning system

The EWSLS used in this project was created by a Japanese firm. Figure 2(a) shows a diagram of the system, while Figure 2(b) shows the warning equipment (see Oyo Corporation 2012). The firm approached the Geotechnical Engineering Research and Development Center (GERD), Kasetsart University in Thailand which then contacted King Mongkut's University of Technology in Thonburi, Bangkok (KMUTT) to test the system. Testing was conducted in the community of Houy Nam Kaew, Krabi province, Thailand, since it was there, in 2011, that 12 community members were killed as a result of a landslide (DMR 2011; Soralump 2011).

Figure 3(a) presents a diagram of the emplacement of the EWSLS in the community. Figure 3(b) shows the placement of the debris flow detector. An unstable soil caused by heavy and continuous

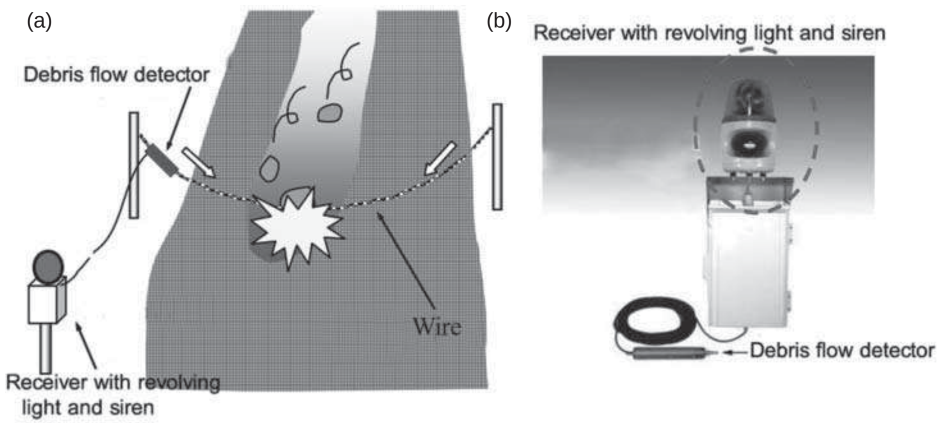

Figure 2. (a) Diagram of the system and (b) warning equipment.

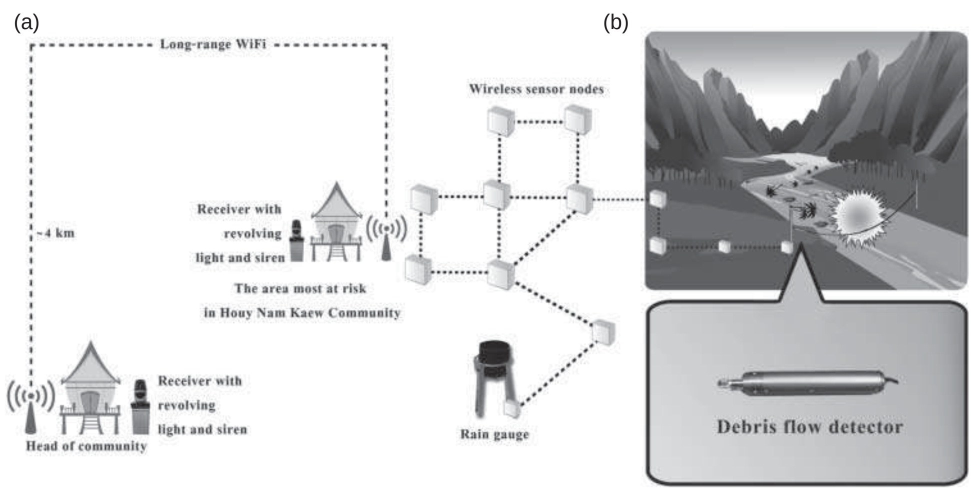

Figure 3. (a) Diagram of the emplacement of the EWSLS in the community and (b) placement of the debris flow detector.

rainfall flows from the mountains, bringing timbers, rocks and accumulated soil along the water channel unit. The soil hits the wire and triggers the debris flow detector to send a signal to wireless sensor nodes. The sensor nodes transmit a signal to a revolving light and siren in the area most at risk. The long-range WiFi transmitter sends another signal to a receiver installed at the residence of the community head. The signal activates the revolving light and the siren. The community head then triggers another alarm in the community. This whole process is referred as an EWSLS. At the same time, the rain gauge sensor installed on top of the mountain is measuring accumulated precipitation to determine the critical rain level which causes debris flow. Measuring the accumulated precipitation is considered as an indirect warning system.

4. Methods

4.1. *Participants*

4.1.1. *Students*

To find volunteer students interested in participating in the project, the PI invited 30 undergraduate, fourth-year students from a foundation engineering course to watch a presentation about landslides in Thailand and to learn about the project. From this group, eight students indicated an interest in participating. These eight students then completed a pre-test that required them to solve a problem about landslides and simulations followed by two hours of instruction about models and simulation of landslides. They then completed a post-test. Subsequently, four of these eight students with the highest scores in the post-test were selected to participate in the project. The participants were four male students in their fourth year of a five-year Bachelor of Science in Industrial Education (major in Civil Engineering). These students had already completed foundation coursework in engineering. Participation in the project would allow them to complete the equivalent of one course credit towards their engineering degree.

4.1.2. *Community participants*

Community participants were selected in the area most at risk in Houy Nam Kaew community, Krabi province, Thailand. The PI along with the four students went door-to-door over a one-day period to invite one community member from each household to participate in the project. As a result of this process, 21 individuals volunteered. These 21 individuals were all interviewed to determine their existing knowledge of and experiences with landslides. All individuals also completed a simple math test (see the following sections). From this group of 21, 9 individuals were selected to participate in subsequent phases of the project. These individuals were representative of the community's range of age of adults as well as a range of mathematical knowledge and education. Participating members ranged in age from 23 to 36. Four of these participants had completed grade four, two had completed grade six and three had completed grade nine. Four were males and five were females.

4.1.3. *External evaluators*

Three external evaluators were asked to evaluate the quality of the model and simulation of the EWSLS created by the students in the context of the project as well as the quality of the teaching materials prepared by students. The three evaluators held master's degrees in related fields and were employed by the Department of Disaster Prevention and Mitigation (DDPM), Ministry of the Interior, Thailand. The evaluators were responsible for coaching and training volunteers from communities in Thailand to prepare for evacuation in the case of a disaster. The evaluators also facilitated sessions in risk areas called 'Community-Based Disaster Volunteer Training'. The DDPM has initiated various training sessions for people in communities at risk in order to create awareness and preparedness and to mobilise their involvement in holistic disaster management. This initiative attempts to prepare communities prone to floods and mudslides by using a participatory approach with people in those communities (Ratananakin 2007).

4.2. *Procedures*

The project was conducted over a period of eight weeks in six phases. Table 1 summarises these phases.

4.3. *Instruments*

Numerous instruments were used in the project. The first of these was a two-part oral questionnaire designed to gain demographic information as well as to assess community members' knowledge about the EWSLS and about the landslide with debris flow in 2011. The math test was also administered orally and consisted of four questions designed to assess members' basic math skills in order for students to ascertain members' ability to calculate response times to the EWSLS. The two-part written questionnaire for external evaluators used a five-point Likert scale.

The purpose of the pre- and post-tests was to assess community members' basic knowledge of landslides and about the EWSLS. The written test was divided into two parts with a total of 25 items. Part I consisted of 20 items with multiple choice questions. Part II consisted of five items with open-ended questions inquiring about the application of EWSLS. Two examples of multiple choice questions are as follows:

(1) What amount of rain will possibly cause a landslide in a three-day period?
  (a) More than 25 mm/day with 75 mm of rain.
  (b) More than 50 mm/day with 150 mm of rain.
  (c) More than 100 mm/day with 300 mm of rain.
  (d) More than 200 mm/day with 600 mm of rain.
(2) When debris hits the sensor, what will likely happen first?
  (a) The siren will sound in the community.
  (b) The community head will announce the evacuation.
  (c) The evacuation warning will be broadcast on TV.
  (d) Nothing will happen. Community members will monitor the situation.

Examples of the open-ended questions are as follows: What is the difference between a landslide and debris flow? Briefly describe how the EWSLS works?

The final instrument was an oral questionnaire designed to assess community members' satisfaction with the teaching by the students. Questions for Part I focused on members' satisfaction with the model and simulation, the teaching about the EWSLS as well as questions about students' interaction with community members. Part II questions invited members to suggest improvements to students' teaching about the EWSLS to community members.

4.4. *Analysis*

Pre- and post-test scores were calculated using their standard deviation (SD) as well as a paired-sample Wilcoxon-signed rank test for significance. For the questionnaire with community members, frequency and percentage were used along with the descriptive statistics of means.

Table 1. Phases of the project.

Phase	Purpose	Duration	Location	Procedure
1.	Collect on-site data about the EWSLS	6 hours 1 day	Landslide site	(a) Four students viewed the site & EWSLS with a member (b) Students took notes about & photos of the EWSLS & of topography & properties (c) Students went door-to-door to invite participation in the project
2.	Assess (a) members' understanding of the system & (b) their basic math skills	15 min/person	Members' homes	(a) Students administered oral questionnaires with 21 members about the 2011 landslide & knowledge of the EWSLS
		15 min/person	Members' homes	(b) Students gave a basic math test to 21 members
		3 days	University classroom	(c) Students analysed results & selected nine members
3.	Create a model of the EWSLS with simulation of landslide	2 days	University classroom	(a) Students designed a contour line of the mountain
		3 weeks	University laboratory	(b) Students created a model of the mountain with a miniature electronic switch
		1 week	DDPM, University classroom , laboratory & library	(c) Students read papers about early warning systems
				(d) Students created a simulation of a landslide
4.	Create materials to teach members	1 week	University classroom & laboratory	(a) Students prepared information & activity sheets for use by nine members (b) Students sent sheets to PI to check accuracy
5.	Conduct an external evaluation	2 hours	University classroom	(a) Students presented their model & simulation to the evaluators (b) Students demonstrated how they would instruct members
		1 hour	University classroom	(c) External evaluators evaluated quality (d) Evaluators made suggestions for further development
6.	Teach members about the system & assess their knowledge & satisfaction	40 min	Community centre	(a) Students conducted pre-test with members
		90 min	Community centre	(b) Students taught members about the EWSLS
		90 min	Community centre	(c) Students engaged members in activities to help them estimate time for evacuation and improve response capability
		1 hour	Community centre	(d) Students gave post-test (e) Students gave satisfaction questionnaire
		2 weeks	University classroom	(f) Students compared scores between pre- and post-test of nine members (g) Students analysed results of satisfaction questionnaire

The students used descriptive statistics (frequency, percentage and means) to calculate and analyse results of the math tests. For the external evaluators' questionnaire, the data were calculated and represented as arithmetic mean score ($\overline{X}$) and SD. The five-point scale used to assess quality was as follows:

- Very good: 4.51–5.00.
- Good: 3.51–4.50.
- Moderate: 2.51–3.50.
- Satisfactory: 1.51–2.50.
- Needs improvement: 1.00–1.50.

The information from evaluators' qualitative assessment of the quality of the model and simulation was collected and categorised, then, cross checked with numerical data. For the satisfaction questionnaire with community members, the data were calculated and represented as ($\overline{X}$) and SD. The items on the Likert scale were categorised as follows:

- Very good: 4.51–5.00.
- Good: 3.51–4.50.
- Poor: 2.51–3.50.
- Very poor: 1.51–2.50.
- Do not know: 1.00–1.50.

5. Results

5.1. *Phase 1*

The purpose of this phase was for students to gain on-site knowledge and understanding about landslides and flow of debris such as timber and mountain rocks. They were able to observe past changes in topography resulting from deforestation for rubber tree plantations and by natural expansion of water channels. Students also observed the actual EWSLS with the debris flow detector, the automatic rain gauge and solar-cell as shown in Figure 4(a) and 4(b), respectively.

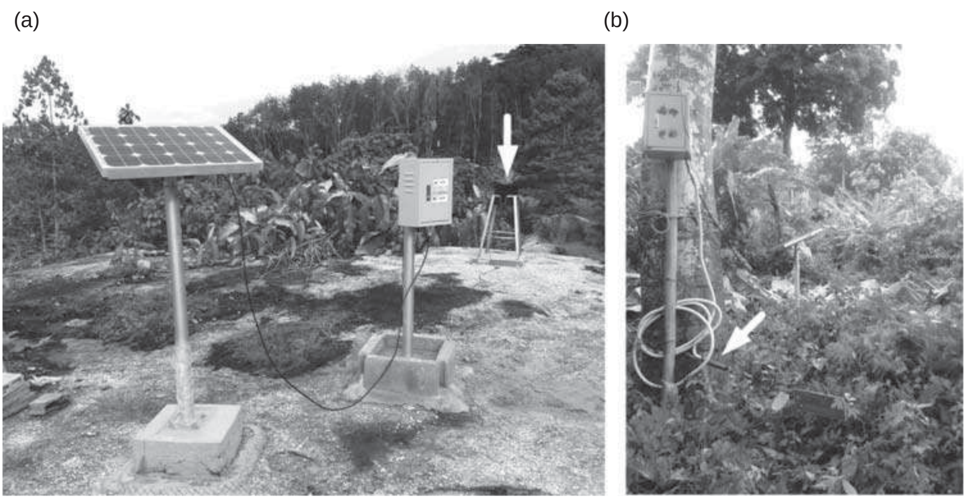

Figure 4. (a) Rain gauge and (b) debris flow detector.

They viewed the middle and foot of the mountain, the wireless sensor nodes, sensor node transmitter, long-range WiFi transmitter and revolving light and siren. At the foot of the mountain, they observed the long-range WiFi transmitter, revolving light and siren.

5.2. *Phase 2*

The purpose of this phase was for students to assess (a) community members' understanding of landslides and of the EWSLS and (b) their basic math skills. Results for this phase revealed that, in relation to the 2011 landslide, rain had been falling continuously for five days. An accumulation of over 1200 mm was unofficially reported by a cup-type rain gauge in the community. Members reported that, at midnight on the sixth day, they had heard a loud noise which they assumed was thunder from a lightning strike. No one evacuated the community. At 5 a.m., the landslide hit the community. There were many injuries, two deaths and property damage to homes and cars. Sixty-seven per cent of the 21 members interviewed indicated that they did not evacuate because they did not expect a landslide to occur. Thirty-three per cent did evacuate because they feared a landslide would occur. Members also reported that if they had received warning, they could have safely evacuated the community.

Ninety-five per cent of the 21 interviewed members reported that they did not know about landslides and 90% did not know about the EWSLS; however, all reported that they were interested in learning about it. Sixty-two per cent reported that local knowledge passed on from generation to generation warned them to watch for changes in the colour of water and presence of turbid water as a warning of a potential landslide. Figure 5 shows students interviewing a community member in her home.

Table 2 presents a summary of the results of the test of community members' basic math skills.

Figure 5. Students interviewing a community member in her home.

Table 2. Results from a basic math test of 21 community members.

Item	Question	Correct result (%)
1.	How many seconds in three minutes?	71
2.	If you tap one rubber tree in 20 seconds, how many trees can you tap in a minute?	67
3.	You are trying to attach a water pipe to your rubber plant. The pipe is four meters long. How many pieces of pipe will you need for 1 km?	24
4.	If water flows 10 m/second how far will the water travel in 1 minute?	62

Table 3. Results of the math test for the nine participating CM.

CM	Item 1	Item 2	Item 3	Item 4	% correct
1.	✓	✓	×	✓	75
2.	✓	✓	×	✓	75
3.	✓	×	×	×	25
4.	✓	✓	✓	✓	100
5.	✓	✓	✓	✓	100
6.	✓	×	×	×	25
7.	✓	✓	✓	×	75
8.	✓	✓	×	×	50
9.	✓	✓	×	✓	75
Total	100	78	33	56	67

CM, community member.

Table 3 presents the results of the math test for the nine individual community members selected to participate in subsequent phases of the study. As the table illustrates, there was a wide variety in these nine members' scores. While community members 4 and 5 were able to answer all questions correctly, members 3 and 6 could only identify 25% correctly. Students selected these nine to be the participants in the project because they represented the diversity of the community in terms of age, gender and range of ability in terms of their math skills.

5.3. *Phase 3*

The purpose of phase 3 was for students to create a model of the EWSLS as well as a simulation of a landslide with debris flow. Using information gathered from the on-site survey, students constructed a model of the mountain with the EWSLS suitable for use with community members. Students designed a contour line of the mountain using Sketch-Up™ software as shown in Figure 6. They created a model from a foam sheet starting from the contour line together with topographical information from the site. The model's base was made of wood with dimensions of 1 m × 2 m × 0.5 m. A model of the mountain with watersheds was made on a scale of 1:2500. The water channel was sloped from the top to the foot of the mountain where the community was located.

The debris flow detector was made from a miniature electronic switch available in a local market. The switch was able to imitate detection of movement of the debris. When debris flow impacted the switch, a signal was sent to an electronic board to trigger an LED light and siren warning. The miniature electronic detection switch was operated together with a small motor to drag a tiny vehicle simulating an evacuation.

To simulate the debris flow in the landslide, the students tried a variety of materials such as engine oil, industrial lubricants, condensed milk and hair conditioner. None of these were suitable to simulate debris flow. Finally, students chose a composite of sodium chloride powder with water and sodium lauryl ether (Texapon N70) because of its time-controllable property and because it was easy to clean. The debris flow imitation speed was approximately 5 cm/second. Figure 7(a) shows students adjusting the model of the EWSLS.

Figure 7(b) shows the miniature electronic detection switch.

5.4. *Phase 4*

The purpose of this phase was to create materials to teach the nine participating community members about the EWSLS. The math test provided the students with insights into members' ability to estimate the speed of the debris flow, the distance needed to travel for evacuation and time needed for community members to evacuate the community in the event of a landslide.

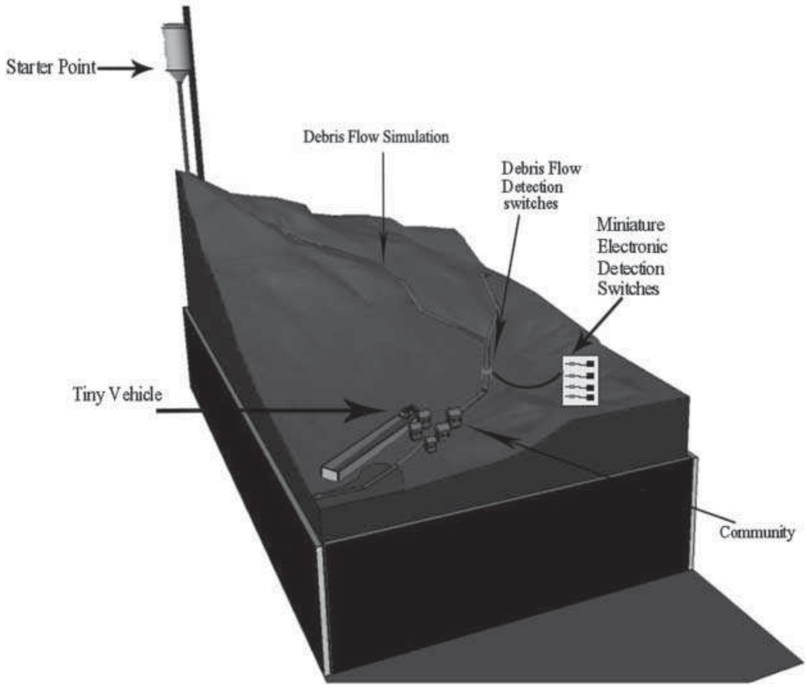

Figure 6. A sketch-up model of the EWSLS.

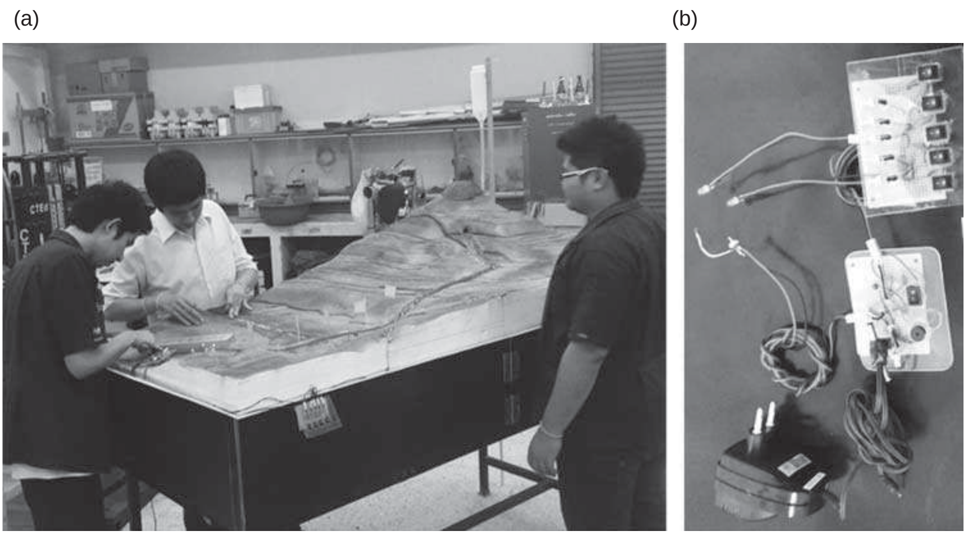

Figure 7. (a) Students adjusting the model and (b) miniature electronic detection switch.

Students created information sheets divided into two parts. Part I featured seven pages with information about landslides such as definitions, types of debris flow, causes and mechanisms. Also included was information about how to react to a landslide. Part II included information about the EWSLS.

5.5. *Phase 5*

The purpose of phase 5 was to conduct an evaluation of (a) students' teaching of community members, (b) the model and (c) the simulation. In order to conduct an evaluation of the students' teaching, the students gave the evaluators copies of the information and activity sheets. So that the evaluators could assess students' teaching, students taught evaluators as if they were teaching community members. The results of (a) are presented in Table 4 and the results of (b) and (c) are presented in Table 5. The overall design of the model and simulation was estimated to be at the *good* (G) level. The three aspects judged to be at a *very good* (VG) level were: the content interest, encouragement of team work and development of community members' knowledge about the EWSLS. The external evaluators suggested that local simple tools such as whistles, wood clappers, fireworks and megaphone should be adapted and used for the EWSLS.

5.6. *Phase 6*

The purpose of this phase was for students to teach community members about the EWSLS. Students used information and activity sheets created in Phase 4 to teach members about definitions of landslides, types of landslide, factors that cause landslides and the mechanism of landslides. Students also used the model and simulation to show community members how the EWSLS functioned. Community members were able to interact with the model and simulation and learn about topography and technical mechanisms.

One of the activity sheets invited participating members to draw the layout of the community. Another sheet showed them how fast the debris flow moved and how to safely install the miniature electronic detection switch. The reason students taught members to install the switch was not to

Table 4. Results of external evaluation for teaching community members.

Item	Evaluation	$\overline{\chi}$	SD	Quality level
1.	Accordance of content with three objectives: I. Make members aware of the importance of the EWSLS II. Help members transfer knowledge of the EWSLS to other members III. Help members know the time needed to evacuate in the event of a landslide	4.33	0.58	G
2.	Suitability of content with timing of presentation	4.33	0.58	G
3.	Content interest	4.67	0.71	VG
4.	The steps of presentation to members	4.33	0.58	G
5.	Suitability of content for members	3.67	0.58	G
6.	Team work in teaching	4.67	0.71	VG
7.	Development of members' skill about landslide monitoring	4.00	1.00	G
8.	Development of members' problem-solving skills	4.33	0.58	G
9.	Development of members' knowledge of the EWSLS	4.67	0.71	VG
10.	Information and activity sheet quality	4.11	0.62	G
11.	Quality of pre- and post-test	4.40	0.51	G

Table 5. Results of the external evaluation of the model and simulation.

Item	Evaluation item	$\overline{X}$	SD	Quality level
1.	Mountain model	4.50	0.65	G
2.	Landslide simulation	4.00	0.58	G
3.	Miniature electronic detection switches	4.42	0.61	G

educate them in technical or engineering skills but to increase their understanding of the system by actual practice.

Community members also participated in a game designed by students for which the object was to calculate the time needed to evacuate the community in the event of a landslide. Students divided the nine community members into two groups. Students imitated the flow of debris from the mountain top. Debris flowed down the mountain passage until it hit the switch, activating a light and the siren. Community members could perceive how the EWSLS worked and calculate the time needed to evacuate before the debris hit the community. Figure 8 shows students instructing the community members. Figure 9 shows some participating community members interacting with the model.

Table 6 presents the results of the pre-test scores ($\overline{X} = 12.78$, SD = 1.30) and post-test scores ($\overline{X} = 23.89$, SD = 1.62). The results revealed a significant difference with a value of $p < .05$. There was significant difference between the mean of pre- and post-test and little difference between the SD of the pre- and post-test.

In terms of participating community members' satisfaction, overall results were at the good level on the five-point Likert scale. Table 7 presents the results of the survey of community members' satisfaction with the teaching. The community members suggested that students should have more

Figure 8. Students instructing community members.

Figure 9. Community members interacting with the model.

Table 6. Comparison between pre- and post-test.

Test	$\overline{\chi}$	SD	Z-test	p-Value
Pre-test	12.78	1.30	−2.67*	.008
Post-test	23.89	1.62		

*$p < .05$

Table 7. Satisfaction of community members.

Items	Topics	$\overline{\chi}$	SD	Quality level
1.	*Content of teaching*	4.17	0.52	G
	Ease of understanding			
	Real-world application			
	Sufficient number of materials for each learner			
	Application in other areas			
2.	*Methods of presentation*	4.42	0.35	G
	Students' presentation style was interesting			
	The oral presentation style was suitable			
	Students were knowledgeable			
	Students covered all content			
3.	*Advantages of the teaching*	4.27	1.47	G
	Members had more awareness of the importance of early warning and evacuation after presentation			
	Members can apply and pass on their knowledge			
	Members fully engaged with the activities			
	Learning promoted community teamwork			
	Learning materials helped members better understand the EWSLS			
	Learning materials helped reduce risk and increase safety			
4.	*Time alloted for teaching*	4.39	0.31	G
	Appropriate overall duration of teaching			
	Appropriate duration of each activity			
5.	*Interaction between students and members*	4.61	0.26	VG
	Interaction between the students and members			
	Students were friendly			
	Students provided an opportunity for members to ask questions			

confidence, interact more with community members and speak more loudly. They also suggested that the students create landslide simulations for teaching the very young and old.

6. Discussion

This project makes evident the need to appreciate the interaction between the artefacts created by engineers and the end users or beneficiaries of these artefacts. Such artefacts may be increasingly sophisticated and technically advanced; however, if they cannot be used effectively, then their value is lost. The four students who participated in this project were able to appreciate directly this complex relationship and interaction between engineering artefacts and their users. In this case, it was obvious that merely installing the early warning system in the community was not enough. Even simply training the community members in its use was not necessarily sufficient since the training needed to be tailored to the knowledge and skill level of those living in the community. These students were not knowledgeable in pedagogy and so they had a challenging task to instruct community members. Yet, they succeeded in this task and, in so doing, possibly indirectly saved lives and helped avoid future injuries and property damage. Such tasks may not be the responsibility of engineers or engineering students. It is organisations such as the DDPM who are charged with this important responsibility. Nonetheless, students' involvement in this project no doubt taught them the value of their profession as well as the need to keep in mind the end users of artefacts that are developed in an engineering context.

Traditionally, engineering students' practical community experiences are limited to internships and work terms. This limitation of students' experiences outside the classroom points to the issue of feasibility and scalability of engaging students in projects of the sort described in this paper. In that regard, the project was conducted under unique circumstances that may not be replicable or sustainable in other contexts. The students and PI benefited from collaboration with industry (the Japanese firm) and a national research institute (GERD). While such collaborations are useful and necessary for real-life learning, they are not always available in all learning contexts. This project, however, illustrates the value of such collaboration. Likewise, the students and PI were able to take advantage of an opportunity to visit a community and interact and work with its members in order to solve real-life problems.

This type of activity may not be feasible in undergraduate engineering courses, especially those with large numbers of students. The issue of group size is an important one. The success of the project described in this paper is partly due to the small size of the group. How can projects of this nature be scaled to accommodate large class sizes? Furthermore, how can engineering students themselves partake in such activities when they are enrolled in programmes that require them to take multiple courses and attend laboratories and complete exams and assignments? One approach that might be taken with large groups is to give them the problem and the raw data and have them work in smaller groups in laboratories to construct models and simulations. However, these approaches limit the real-world experiences and the 'messiness' inherent in solving problems in the real word.

Advances in information and communication technologies offer alternative approaches to project-based learning that may be feasible with large groups. Choo et al. (2003) described a series of case studies in which students analysed real data and engaged in role-playing to engage in simulated project-based learning in engineering. Gordon, Bos, and Knox (2003) described a computer-based simulation using videos and spreadsheets with real data. While such projects may be more feasible, they may eliminate the unpredictability encountered in real situations which requires students to think in creative and critical ways, to make decisions, devise novel solutions and plan for alternative approaches. Simulations may not always allow students to engage in interpersonal interactions as did students in the project described in this paper. For example, they did not know before visiting the community what the members' understanding, knowledge or education level might be. They had to therefore develop their plans based on relevant data they gathered in the community. At various points in the process, they had to adopt different roles to become researchers, teachers and students.

As such, simulated, computer-based projects may not provide students with the opportunity to develop soft skills related to communication and interaction. The call for papers by a journal of engineering education (Bayo et al. 2013) highlights the growing importance of soft skills in the field. Students participating in the project reported on in this paper were required to interact and communicate with community members on a daily basis. They had to assess the knowledge of these individuals and tailor their interventions to accommodate this knowledge. These interactions provided students with an opportunity to translate engineering knowledge into a form that was comprehensible for lay persons. The skills gained in this context are likely to make students more ready for their future employment and thus more marketable to employers. Having to teach community members also afforded students to learn, not only by doing but by explaining to others what they themselves knew, i.e. learning by teaching.

This project did not include any formal means to assess students' knowledge and skills gained as a result of participation in this project. However, assessment took place formatively and constantly on an ongoing basis by the PI. The PI acted as facilitator to guide students' participation and, because the project consisted of only four students, he was able to closely monitor students' activities through direct observation. In this capacity, he could pose questions, check for understanding, observe their interactions with community members and ensure that students were on-task and provide advice. Evaluation was also conducted authentically. In this regard, community members completed a survey to provide feedback to the students related to their satisfaction about knowledge gained and about their learning. The pre- and post-tests of community members also provided a measure of the success of students' teaching. The quality of the model and simulation was assessed by the external evaluators. Thus, the assessment in this project was complex and multifaceted. The four students were all given a passing grade.

Other forms of assessment may be needed for larger groups when it is not possible or feasible for the instructor or facilitator to constantly monitor students. Chan (2012b) described some of these approaches to assessment as follows:

> There are some established approaches such as reflective journals, presentations, oral interviews, posters, direct observations, project reports, portfolios and expectation and post experience surveys currently used to assess service learning in higher education. In general, most community service learning uses a combination of these assessment approaches. (30)

7. Conclusions

This paper reported on a project that involved students in the design, construction and testing of a model of an existing early warning system with simulation of debris flow in a context of a landslide. Students also assessed rural community members' knowledge of this system and subsequently trained them in its use to improve their response capability in order to be able to evacuate the community in the event of a landslide. One of the benefits of this project is that students could develop skills that have relevance beyond the classroom and that can be transferred to real life. However, it was beyond the scope of this project to measure or assess the transfer of skills students may have gained. This type of assessment might be carried out in separate studies. Likewise, this project did not directly assess the soft skills that students may have gained in the context of their experiences. These are challenging to assess since they may be highly individualised and dependent on the characters of the particular students. Finally, we do not know if the intended improvements in community members' response capability will be transferred to a real-life situation.

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