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ORIGINAL PAPER

Comparison of Cross Culture Engineering Ethics Training Using the Simulator for Engineering Ethics Education

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Abstract This paper describes the use and analysis of the Simulator for Engineering Ethics Education (SEEE) to perform cross culture engineering ethics training and analysis. Details describing the first generation and second generation development of the SEEE are published in Chung and Alfred, Science and Engineering Ethics, vol. 15, 2009 and Alfred and Chung, Science and Engineering Ethics, vol. 18, 2012. In this effort, a group of far eastern educated students operated the simulator in the instructional, training, scenario, and evaluation modes. The pre and post treatment performance of these students were compared to U.S. Educated students. Analysis of the performance indicated that the far eastern educated student increased their level of knowledge 23.7 percent while U.S. educated students increased their level of knowledge by 39.3 percent.

Keywords Engineering ethics · Training · Simulators · Cross culture

Introduction

A consideration of multinational organizations is the issue of cross cultural engineering ethics. This is particularly important in the Civil, Chemical, and Petroleum engineering fields. In the case of natural disasters such as earthquakes and tsunamis engineers from many different countries and cultures may be involved in the reconstruction efforts. For this reason, engineering ethics training with a common structure will hopefully reduce the possibility of engineering ethics issues.

A number of research efforts have focused on the concept of cross cultural engineering ethics using a variety of educational approaches. An early examination

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of the differences between far east Indian and U.S. students was conducted by Ansari 2001. Using a non-computerized problem solving approach, Ansari noted distinct qualitative differences between the two groups. Another examination of cross-cultural issues using both quantitative and qualitative analysis using a case study approach was executed by Chang and Wang 2011. Most recently Wang and Thompson 2013 suggested a number of different methods for identifying the differences between ethics standards in different countries.

Prior to the development of the Simulator for Engineering Ethics, the majority of educational approaches included dogma, heuristics, and case studies (Haws 2002). In the case of dogmatic approaches, students are familiarized with a pre-formulated list of do and do not activities related to the ethical practice of engineering. A slightly more sophisticated approach involves the use of simple scenarios to which the student attempts to apply the same pre-formulated ethical principles. The third approach involves the use of actual or hypothetical cases in which the student attempts to analyze the situation and provide possible courses of action. In its most effective form, students must act as actors/agents rather than observers in the ethical situation and decide whether to gather more evidence, how to raise the ethical issue, and how best to generate support for their ethical concerns (Whitbeck 1996).

Most recently, a number of organizations have sought to increase the utility of these basic approaches by improving their accessibility through the Internet. These include the development of the on-line Ethics Center for Engineering and Science Case Western University (2013), the National Institute for Engineering Ethics (Texas Board of Professional Engineers 2013), the Engineering Ethics web site (2013), the ethics web site section of the National Society of Professional Engineers (National Society of Professional Engineers Ethics 2013) and others (Cummings and Lo 2004; Herkert 1997; Steneck 1999). Resources from these organizations include individual on-line courses, manuscripts, case studies, videos, DVDs, and tests for engineering ethics training. While many of these resources may be used in isolation, more effective approaches include the use of multiple forms of the above media in order to maximize the involvement of students in examining ethical situations from a broad perspective (Loui 2005, 2006).

The use of an interactive multimedia training simulator for educating students in engineering ethics was introduced by Chung and Alfred 2009 and Alfred and Chung 2012 This was based on the concepts that:

- The most effective way to provide this type of realistic training would be to actually put the student in an actual situation involving engineering ethics.
- It is unrealistic and unethical to create these types of real life situations solely for the purpose of engineering ethics education.
- Simulators offer realistic training that might not otherwise be possible due to operational, cost, or time limitations.

In these research efforts, Chung and Alfred determined that the Simulator for Engineering Ethics was effective for training U.S. engineering students on National Society of Professional Engineers engineering ethics standards.

Problem Statement

The differences in cross cultural engineering ethics will continue to be an issue for multi-national and international engineering efforts. Several methods have been proposed to identify these differences. To help reduce the differences in engineering ethics, common training can be considered. The use of the previously statistically validated Simulator for Engineering ethics is one means of determining the differences in NSPE accepted engineering ethics in cross cultural situations.

Methodology

For this effort, the Simulator for Engineering Ethics Education was used in a training session focusing on engineering ethics for a group of 16 far eastern students attending a short management training course at the University of Houston during 2013. Figure 1 illustrates the opening screen of the Simulator for Engineering Ethics. The individuals were given an introduction on the operation of the program and then each participant individually utilized the instructional, training, and scenario modes of the program. Prior to and after using the simulator, the participants utilized the evaluation mode to assess their pre and post treatment level of engineering ethics knowledge.

The Simulator for Engineering Ethics operates in four different modes. These include instructional, training, scenario, and evaluating modes. The instructional, training, and evaluating modes are similar between the first and second generation programs. The instructional, training, and evaluation mode are briefly summarized in the following paragraph. Readers desiring additional details on these operating modes are directed towards Chung and Alfred 2009 and Alfred and Chung 2012.

In the instructional mode, users are presented with fundamental information about engineering ethics, rules of practice, and professional obligations. These follow the National Society of Professional Engineers code subjects. Fundamental Canons cover the six basic principles by which professional engineers are expected to conduct themselves. The Rules of Practice and the Professional Obligations sections elaborate on the six basic principles and provide specific examples of appropriate conduct. In the training mode, users are presented with specific limited situations involving the recognition and response to the engineering ethics subjects presented in the instructional mode. Lastly, in the evaluation mode users are provided with an objective means of assessing the level of the user's knowledge. This mode can also be used in a before and after mode to assess increased learning. There are a total of 20 randomly generated questions which are based on the National Society of Professional Engineers Ethics Code test.

Limited Statistical Comparison

A limited statistical comparison of the teaching effectiveness was performed within and between the far eastern and the U.S. educated students. Prior to use of the

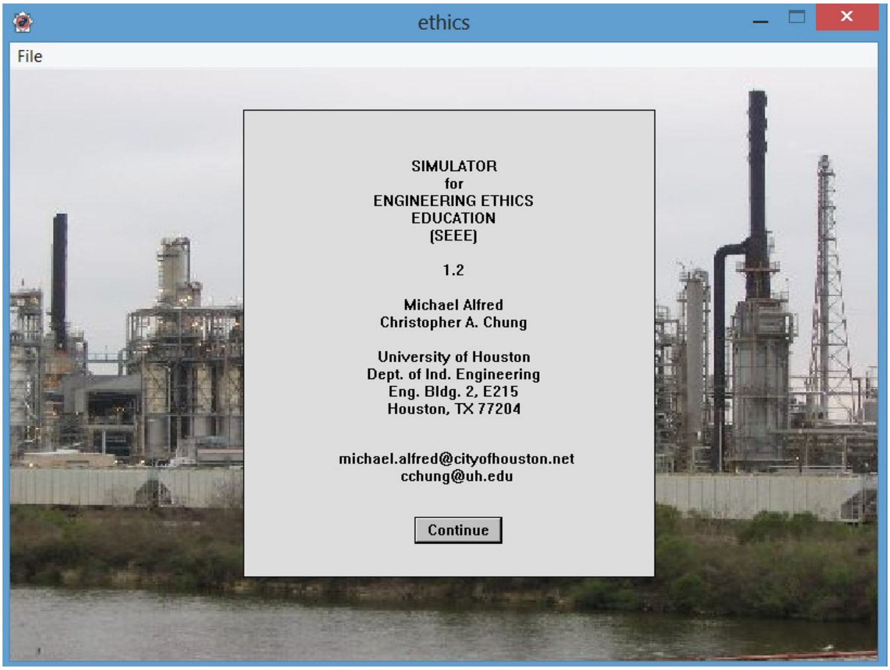

Fig. 1 Simulator for engineering ethics

simulator, the participants were given a known group validated 20 question pre-test on engineering ethics. Following the use of the simulator, both groups were given a post-test on engineering ethics. The test scores on a scale of 0–20 are grouped as data sets according to treatment groups and their pre- and post-test scores in Table 1.

Non-Parametric Test to Determine Initial Level of Knowledge Differences

To determine if there was a difference in initial engineering ethics knowledge between the far eastern and the U.S. students, a Mann–Whitney *U* test was performed. This particular test was utilized due to the low participant numbers which would normally preclude an independent *t* test approach.

The formal *U* test procedure is summarized below:

1. Hypotheses:
   Null hypothesis: populations are identical
   Alternative hypotheses: populations are not identical
2. Level of significance, alpha: 0.05
3. Criterion: reject null hypotheses if z is exceeds the + or − critical value of 1.96.
4. Test statistic calculations: The test statistic is calculated using the following steps.

Table 1 Summary statistics

	PREFAREAST	POSTFAREAST	PREUS	POSTUS
N	16	16	12	12
Mean score	9.75	12.06	10.58	14.75
Standard deviation score	2.54	2.08	1.98	2.30

a. Order data in ascending order and merge data sets
b. U1 = W1 − n1(n1 + 1)/2, where W1 is the sum of the ranks of data set 1 (far eastern)
c. U2 = W2 − n2(n2 + 1)/2, where W2 is the sum of the ranks of data set 2 (US)
d. U1 = min (U1, U2)
e. μ = n1*n2/2
g. Sigma1 squared = n1*n2*(n1 + n2 + 1)/12
h. Z = (U1 − μ)/sigma1

Using the above procedure, Z = −0.97.

5. Decision:
   The test statistic Z = −0.97 is between – and + 1.96. Thus the null hypotheses of identical populations cannot be rejected at an alpha level of 0.05. This means that there is evidence to support the statement that the initial level of engineering ethics knowledge between the far eastern and the U.S. students was statistically similar.

Paired *t*-tests to determine the teaching effectiveness of the Simulator

To determine the teaching effectiveness of the Simulator for Engineering Ethics, a paired *t*-test was performed for both the far eastern and the U.S. students. The paired t test is a comparison of means test based on the difference in scores for a set of before and after treatment observations for the individuals in the study. The actual statistical calculations are based on the mean differences μ_D and standard deviation of the $S_{D.}$ By performing the paired *t* test calculations, the effect of the training can be determined taking into account the variation in data. The test is performed at an alpha level of 0.05. This means that there is only a 5 % probability of rejecting the null hypotheses and making a type I error of concluding that there is a difference when in reality there is not.

The formal paired *t* test procedures for the far eastern students is summarized below:

1. Hypotheses:
   Null hypothesis: population mean difference = 0
   Alternative hypotheses: population mean difference > 0
2. Level of significance, alpha: 0.05

3. Criterion: reject null hypotheses if t is exceeds the critical value with the n−1 degrees of freedom for the set of paired data. For the far eastern students, n = 16, degrees of freedom are 15 and the critical t value is 1.753.
4. Test Statistic Calculations: The test statistic is calculated using Eq. 1.

$$t = \frac{\overline{D} - \mu_D}{S_D/\sqrt{n}} \tag{1}$$

where D bar is the average of the differences of the before and after scores. $\mu_D = 0$ and S_D is the standard deviation of the differences of the before and after scores. For the far eastern students $t = 5.57$ for the U.S. students $t = 4.95$.

5. Decision:
   The far eastern students' test statistic $t = 5.57$ exceeds the critical value of 1.753. The null hypotheses must be rejected at a statistically significant level of 0.05. This provides evidence that the Simulator for Engineering Ethics has a statistically significant level of training at an alpha level of 0.05.

For the U.S. students the experiment was as follows.

1. Hypotheses:
   Null hypothesis: population mean difference = 0
   Alternative hypotheses: population mean difference > 0
2. Level of significance, alpha: 0.05
3. Criterion: reject null hypotheses if t is exceeds the + or – critical value with the n−1 degrees of freedom for each of the two sets of paired data. For the U.S. students, n = 12, degrees of freedom are 11 and the critical t value is 1.796.
4. Test Statistic Calculations: The test statistic for each set of paired data is calculated using Eq. 1.

$$t = \frac{\overline{D} - \mu_D}{S_D/\sqrt{n}} \tag{1}$$

where D bar is the average of the differences of the before and after scores. $\mu_D = 0$ and S_D is the standard deviation of the differences of the before and after scores. For the U.S. students $t = 4.95$

5. Decision:
   The U.S. students' test statistic $t = 4.95$ exceeds the critical value of 1.796. The null hypotheses must be rejected at a statistically significant level of 0.05. This provides evidence that the Simulator for Engineering Ethics has a statistically significant level of training at an alpha level of 0.05 for the U.S. students.

Non-Parametric Test to Determine Final Level of Knowledge Differences

To determine if there was a final difference in engineering ethics knowledge after the use of the Simulator between the far eastern and the U.S. students, a Mann–

Whitney U test was performed. This particular test was utilized due to the low participant numbers which would normally preclude an independent t-test approach.

The formal U test procedure is summarized below:

1. Hypotheses:
   Null hypothesis: populations are identical
   Alternative hypotheses: populations are not identical
2. Level of significance, alpha: 0.05
3. Criterion: reject null hypotheses if z is exceeds the + or – critical value of 1.96.
4. Test statistic calculations: The test statistic is calculated using the following steps.
   a. Order data in ascending order and merge data sets
   b. $U1 = W1 - n1(n1 + 1)/2$, where W1 is the sum of the ranks of data set 1 (far eastern)
   c. $U2 = W2 - n2(n2 + 1)/2$, where W2 is the sum of the ranks of data set 2 (US)
   d. $U1 = \min(U1, U2)$
   e. $\mu = n1*n2/2$
   f. Sigma1 squared $= n1*n2*(n1 + n2 + 1)/12$
   g. $Z = (U1 - \mu)/\text{sigma1}$
   Using the above procedure, $Z = -2.72$.
5. Decision:The test statistic $Z = -2.72$ exceeds –1.96. Thus the null hypotheses of identical populations is rejected at an alpha level of 0.05. This means that there is evidence to support the statement that the final level of engineering ethics knowledge between the far eastern and the U.S. students was statistically dissimilar.

Conclusions

The Simulator for Engineering Ethics determined that there is no statistically significant difference in the initial level of engineering ethics knowledge between the far eastern and the U.S. students.

The paired t-tests for both the far eastern and the U.S. students indicated that the NSPE based Simulator for Engineering Ethics is effective in teaching engineering ethics in different cultures. With the far eastern students there was an increase of 23.7 percent in knowledge while the U.S. students exhibited an increase in 39.4 percent in knowledge.

The final U test indicated that the final level of engineering ethics knowledge was statistically dissimilar between the far eastern and the U.S. students using the Simulator. The U.S. students exhibited a 22.3 percent greater level of engineering ethics knowledge over the far eastern students.

This analysis indicates that the Simulator for Engineering Ethics has a statistically significant effect on the far eastern students, but the level of learning was not as great as that of the U.S. students. A primary reasons for this may be the language barrier as the Simulator is presented in English. During the testing process, the far eastern students asked several questions related to the ethics training. A typical question was "what does sign off" mean. This was in respect to approval of a questionable engineering change order. Thus, although engineers from another culture may speak English fluently, engineering jargon or engineering specific acronyms may result in misunderstandings.

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References

Alfred, M., & Chung, C. (2012). Simulator for Engineering Ethics Education (SEEE2) Design, Development, and Evaluation of a Second Generation Interactive Simulator for Engineering Ethics Education (SEEE2). *Science and Engineering Ethics, 18*(4), 689–697.

Ansari, A. (2001). The greening of engineers: A cross cultural experience. *Science and Engineering Ethics, 7*(1), 105–115.

Case Western University. (2013). On-line ethics center for engineering and science

Chang, P., & Wang, D. (2011). Cultivating engineering ethics and critical thinking: A systematic and cross-cultural education approach using problem-based learning. *European Journal of Engineering Education, 36*(4), 370–390.

Chung, C. A., & Alfred, M. (2009). Design, development, and evaluation of an interactive simulator for engineering ethics education (SEEE). *Science and Engineering Ethics, 15*, 189–199.

Cummings, M. L., & Lo, J. (2004). *Globalizing engineering ethics education through web-based instruction* (pp. 92–95). Worcester, MA: IEEE International symposium on technology and society.

Haws, D. R. (2002). Using the web to integrate ethics in the engineering curriculum. In Proceedings Frontiers in Education Conference 3: S4F/7-S4F/12.

Herkert, J. R. (1997). Making connections: Engineering ethics on the world wide web. *IEEE Transactions on Education, 40*(4), 7–14. doi:10.1109/13.759672.

Loui, M. C. (2005). Educational technologies and the teaching of ethics in science and engineering. *Science and Engineering Ethics, 11*, 435–446. doi:10.1007/s11948-005-0012-5.

Loui, M. C. (2006). Assessment of an engineering ethics video: Incident at Morales. *Journal of Engineering Education, 95*(1), 85–91.

National Society of Professional Engineers Ethics. (2013). Web site section, http://www.nspe.org/ethics/home.asp.

Steneck, N. H. (1999). Using the web for teaching engineering ethics across the curriculum. Presented at the OEC International Conference on Ethics in Engineering and Computer Science.

Texas Board of Professional Engineers. (2013). http://www.tbpe.state.tx.us/. Texas Technological University, National Institute for Engineering Ethics, 2008. http://www.niee.org/pd.cfm?pt=NIEE.

Texas A&M University. (2013). Engineering Ethics. Web Site, http://ethics.tamu.edu/.

Wang, G., & Thompson, R. (2013). Incorporating global components into ethics education. *Science and Engineering Ethics, 19*(1), 287–298.

Whitbeck, C. (1996). Ethics as design: Doing justice to moral problems. *The Hastings Center Report, 26*(3), 9–16. doi:10.2307/3527925.