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Abstract

Safety awareness has been identified by the College of Engineering at Iowa State University as one of the core student competencies tracked as part of the ABET accreditation process. However, engineering students, and their internship supervisors, were found to rank this competency low compared to other competencies. To increase competency and accomplish safer designs, engineers need to be trained in safety engineering fundamentals. However, it would be extremely difficult to add this content to already overflowing engineering curricula. Thus, an autonomous on-line safety awareness enhancing curriculum was developed and deployed. This work suggests utilizing a decision making simulation to assess the effectiveness of the proposed program on a level of safety awareness has merit. The results of the analyses of the simulation indicated a significant shift in safety awareness. The implementation of this approach for assessment of programs requires little effort on behalf of the instructor and quickly provides results to both the students and the faculty after students completed the program. This assessment process can replace current methods (e.g. feedback from graduates during exit interviews and from graduates' supervisors in the workplace), which are indirect measures that involve a more tedious process. Ultimately, the suggested methodology can be automated and provide assessment almost instantaneously.

Keywords

safety awareness; competency; decision making simulations; program assessment

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Testing the Effectiveness of an On-Line Safety Module For Engineering Students*

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Safety awareness has been identified by the College of Engineering at Iowa State University as one of the core student competencies tracked as part of the ABET accreditation process. However, engineering students, and their internship supervisors, were found to rank this competency low compared to other competencies. To increase competency and accomplish safer designs, engineers need to be trained in safety engineering fundamentals. However, it would be extremely difficult to add this content to already overflowing engineering curricula. Thus, an autonomous on-line safety awareness enhancing curriculum was developed and deployed. This work suggests utilizing a decision making simulation to assess the effectiveness of the proposed program on a level of safety awareness has merit. The results of the analyses of the simulation indicated a significant shift in safety awareness. The implementation of this approach for assessment of programs requires little effort on behalf of the instructor and quickly provides results to both the students and the faculty after students completed the program. This assessment process can replace current methods (e.g. feedback from graduates during exit interviews and from graduates' supervisors in the workplace), which are indirect measures that involve a more tedious process. Ultimately, the suggested methodology can be automated and provide assessment almost instantaneously.

Keywords: safety awareness; competency; decision making simulations; program assessment

1. Introduction

1.1 Motivation

Safety issues are critical to every practicing engineer.

The first fundamental canon in the Code of Ethics for Engineers is "Hold paramount the safety, health, and welfare of the public" [1]. Because of this, safety concerns need to be incorporated in all engineering design decisions. While it is common practice to report to accrediting bodies that safety is taught to engineers as part of their design curriculum, safety engineering is not traditionally a formal component of undergraduate engineering curricula (with the exception of some industrial engineering degrees).

1.2 The competency approach

The College of Engineering (CoE) at Iowa State University (ISU) established a competencies-based evaluation system for program outcomes. Hanneman, Mickelson, Pringnitz, and Lehman [2] discuss the efforts for establishing repeatable and reproducible scales for ABET outcomes. Brumm, Hanneman, and Mickelson [3] present the development of a framework for assessment of program outcomes through workplace competencies. More than 200 stakeholders (e.g., employers, faculty and staff, alumni, students, parents) have participated in the development of a list of workplace competencies that serve as the foundation for the assessment of ABET outcomes at ISU. Each competency was further refined to a set of measurable key actions. Following an intensive validation session, an on-line assessment system was created [4].

While it has not been formally taught, safety awareness has been identified by the CoE at ISU as one of the core student competencies tracked as part of the ABET accreditation process. Engineering students as well as their internship supervisors rank this competency low compared to other competencies (among the lowest six ranked competencies, out of 15). Significant efforts are invested toward increasing student competencies and assessing progress without overloading the curricula (e.g., Mickelson, Harms, and Brumm [5]). This work presents the development and deployment of an autonomous on-line safety awareness enhancing curriculum (SAEC). The study introduces an inno-

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vative approach that utilizes a decision making simulation to assess the effect of SAEC on enhancing the level of safety awareness among engineering students at ISU. Current assessment efforts at ISU are perception based, utilizing ratings on a 5-point Likert Scale. While perception-based evaluations carry merit, these surveys have several deficiencies, such as very low accuracy, bias, and lack of sensitivity needed to measure improvement/derogation in small increments. The assessment with decision making simulation documents cognitive processes. Subjects are not aware of the procedure associated with analyzing the results of the simulation, thus, bias associated with awareness of the subject matter is avoided. Furthermore, the analysis of the decision portraits provides more insights on the effect of the intervention by, not only measuring shifts in awareness, but also by understanding the cognitive processes associated with these shifts.

1.3 Decision making

Classic theories of choice stress decision making as a rational choice process. The rational school of choice argues for a classical decision strategy in which the decision makers identify a set of alternatives and a set of decision criteria, assign a weight to each one of the criteria, calculate the rating for each alternative, and select the alternative with the most favorable score as a course of action.

Numerous studies, since the early-mid 20^{th} century, emphasized that these ideal typical theories fail to recognize formulation stages of decisions (e.g., Dillon [6], March and Olsen [7]). Payne, Bettman, and Johnson [8] introduced the tradeoff off between attaining accuracy and limiting cognitive efforts in their accuracy-efforts framework for decision makers. Their framework was established based on Newell and Simon's fundamental work on human problem solving [9]. The key assumption of accuracy-efforts is that people tend to strategize their information processing to minimize efforts. One group of strategies is known as non-compensatory decision rules. For example, when employing Elimination by Aspects [10], a non-compensatory mechanism, the decision maker considers one or more critical dimensions across all alternatives. Alternatives that fall below minimal thresholds on critical dimensions are eliminated. Thus, in a decision making task where safety is a dimension in the decision problem, a highly safety conscious individual who uses EBA will review information on safety and eliminate alternatives that fall below the threshold for safety without review of the other aspects of these alternatives. Therefore, for this individual, the amount of information reviewed on safety as a decision dimension will be higher than the amount of information reviewed on other dimensions. Consequently, the ratio between the amount of information reviewed on a safety decision dimension and the average amount of information reviewed on the other decision dimensions may reflect the relative priority of the safety dimension with respect to the other dimensions. Similarly, a highly safety conscious individual will assign more weight to the safety dimension than a less safety conscious individual.

Keren, Mills, Freeman, and Shelley utilized a decision making simulation based on the review above to "capture" the relationship between level of safety climate and safety decision making in industrial organizations [11]. This study extends the framework to assess the effectiveness of SAEC on enhancing the level of safety awareness among engineering students.

2. Methodology

2.1 Intervention

Curriculum: to address the impracticality associated with adding a required safety course in already packed engineering curricula, the authors designed and implemented an autonomous on-line Safety Awareness Enhancing Curriculum (SAEC) module for engineering seniors. Faculty from the Occupational Safety program at the department of Agricultural and Biosystems Engineering (ABE) considered a variety of criteria in their decision on the content for SAEC. The decision was to establish SAEC with three sub-modules having the following content:

- Safety and health regulations and standards:
  - Relevant organizations
  - Survey of safety standards
  - Sources for safety and health information
- Hazard evaluation and control:
  - Toxic effects
  - Toxicity and risk assessments
  - Occupational hearing loss
  - Flammable and combustible materials
  - Combustion and fire extinguishing
- Systems and Risk:
  - Survey of risk
  - Risk management
  - Methodologies for risk assessments and control

To develop an autonomous system, narrated PowerPoint^{TM} presentations were prepared and uploaded to WebCT^{TM}. Each presentation was limited to 15 minutes to avoid loss of engagement due to the length of the content. The SAEC module included seven assessment sessions (multiple choice questions) that were deployed utilizing WebCT's automated assessment module. Each assessment session included a large bank of questions, to reduce the likelihood of information transfer between students. Students received grades for each session only after all of the students completed the assessment session.

The Course: the motivation from which this project stems is to ensure that engineering students will be exposed to a safety awareness enhancing curriculum before graduating. As mentioned above, adding a safety course to already overflowing engineering curricula jeopardizes successful implementation and deployment of such a course.

The programs in the majority of the departments at the CoE at ISU include a set of senior capstone design courses spanning two semesters. The authors pursued implementation of the pilot SAEC in the first semester of the design sequence, ultimately envisioning successful completion of SAEC as a required part of these senior design courses. The pilot for this project was then delivered as part of the first senior design course in ABE at ISU. Completion of the module, participating in a Plus/Delta study [12], and completion of a decision making simulation awarded students credit equivalent to two weekly homework assignments.

2.2 Decision making simulation

Decision process tracing methodology was implemented using the Decision Mind software [13] to capture decision making characteristics. Process tracing is a methodology designed to identify information accessed during the decision process and the order in which the information is viewed. Data gathered from process tracing can then be used to make inferences about which decision strategies are employed en route to a choice [8].

The computerized Decision Mind records key features of the decision-making process:

(1) the sequence in which respondents acquire information;
(2) the number of items that respondents view for every alternative along each dimension;
(3) the amount of time that elapses from the time respondents begin the task until they make their choice;
(4) the choice.

Using process-tracing techniques, a decision portrait of the subjects can be presented. A variety of indices can be calculated based on the information search patterns [e.g., 11, 14–17].

The core structure of the Decision Mind (DM) platform is a matrix of decision alternatives (A_i) and decision dimensions (D_j), as presented in Fig. 1. The decision maker is seated in front of a computer monitor and is asked to choose an alternative from a set of alternatives (A_1, A_2,..) based on information s/

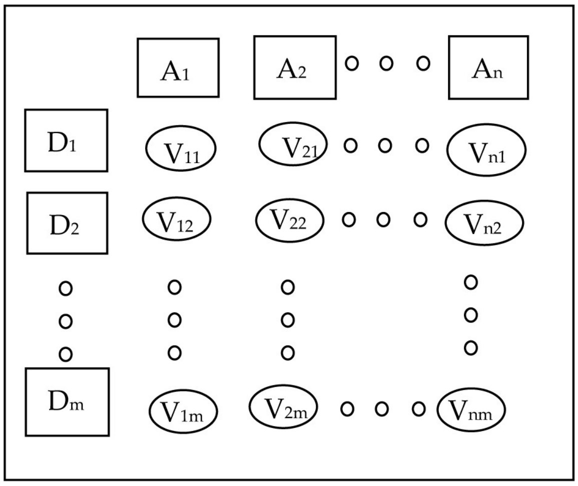

Fig. 1. Decision matrix.

he acquires from the Decision Mind, by "clicking" on information buttons V_{ij}. The information available in V_{ij} represents the evaluation of a given alternative (A_i) on a given dimension (D_j). For example, when selecting among alternative car models to purchase, gas mileage, mechanical reliability, and insurance costs are among potential decision dimensions.

In this study subjects have been asked to confront the following decision dilemma:

> You are the product manager for a growing fast food enterprise. Your firm's technical office delivered sets of designs for four prototypes of food preparation and processing systems. A team you have assigned analyzed the design of the prototypes and concluded that technically all four prototypes are in an acceptable level. To assist with the decision process, the team arranged further information for you to review in the matrix below. The information includes evaluation of each one of the four prototypes on the following four dimensions: Hygiene, Capacity, Safety, and Instrumentation. Your task is to select the design of the prototype that the company should go with.

The subjects are then asked to use the right column in the decision matrix to add weights, on a scale of 0 to10, for the importance of each decision dimension with respect to the other dimensions (subject could rate all dimension 10. In the analysis, the weights were normalized to a 0 to100 scale). Then they are asked to review information on the evaluation of the prototypes with regard to the dimensions, by clicking the "Select" button on the intersection between the column of the prototype of interest and the row of the dimension of an interest. Fig. 2 presents a screen shot of the decision matrix on a PC monitor. Appendix A lists the information in the decision matrix. To avoid bias associated with location of information in the decision matrix, a set of four matrices with different orientations of alternatives and dimensions were used in the simulation.

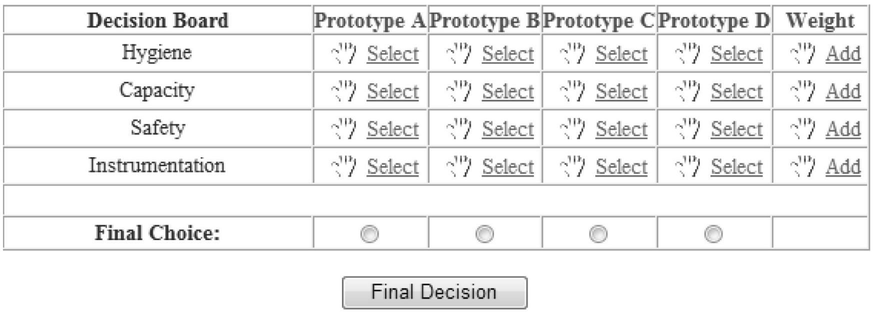

Fig. 2. The decision matrix on a PC monitor.

The scenario was developed by four faculty from ABE at ISU. The process of developing the decision scenario followed, in principle, the Delphi procedure, until a consensus was gained.

The focus of this study is on the following process characteristics of decision making processes:

(1) Dimension-oriented information acquisition. The dimension search indices measure how much information the decision maker acquires on one dimension relative to others [11];
(2) Weights. Subjects are asked to assign weights (on a scale of 0 to10) to each one of the dimensions. The weights reflect the relative importance the decision maker assigns to each one of the dimensions with respect to the other dimensions (normalized to a 100 scale);
(3) Final Choice. Subjects are asked to make a final choice on the alternative they prefer.

A dimension search index measures the number of times information bins in a certain dimension (Dj) are reviewed relative to the average number of times information bins are reviewed in other dimensions. The index is based on an index introduced by Keren et al. [11]. The decision dimensions in the decision task herein are Hygiene, Capacity, Safety, and Instrumentation. The dimension search indices for each one of these dimensions are HSI, CSI, SSI, and ISI, respectively. Equations 1, 2, 3, and 4 are used to calculate HSI, CSI, SSI, and ISI, respectively:

$$\mathrm{HSI} = \frac{N_j}{\frac{1}{(n-1)} \sum_{i=1, i \neq \mathrm{Hygiene}}^{n} N_i} \tag{1}$$

Where,

$\mathbf{N_j}$ represents the number of times information bins in the Hygiene dimension are visited,

$\mathbf{N_i}$ represents the number of times information bins in the other dimensions *i* are visited,

n represents the number of dimensions in the decision matrix (n=4).

Similarly,

$$\mathrm{CSI} = \frac{N_j}{\frac{1}{(n-1)} \sum_{i=1, i \neq \mathrm{Capacity}}^{n} N_i} \tag{2}$$

Where, $\mathbf{N_j}$ represents the number of times information bins in the Capacity dimension are visited

$$\mathrm{SSI} = \frac{N_j}{\frac{1}{(n-1)} \sum_{i=1, i \neq \mathrm{Safety}}^{n} N_i} \tag{3}$$

Where, $\mathbf{N_j}$ represents the number of times information bins in the Safety dimension are visited, and:

$$\mathrm{ISI} = \frac{N_j}{\frac{1}{(n-1)} \sum_{i=1, i \neq \mathrm{Instrument}}^{n} N_i} \tag{4}$$

Where, $\mathbf{N_j}$ represents the number of times information bins in the Instrumentations dimension are visited.

The dimension search indices range from 0 (none of the information bins in a given dimension were visited) to infinity (information search was conducted only in the given dimension). The more emphasis a decision maker puts on a certain dimension in her/his information acquisition, the larger the value of the index for this dimension will be.

2.3 *Hypotheses*

It is anticipated that both the weight of safety as a decision dimension and the emphasis on safety in information search will increase following exposure to SAEC. Therefore, we hypothesize the following statements:

H1: Weight of safety as a decision dimension will increase following exposure to SAEC;

H2: Safety Search Index (SSI) will increase following exposure to SAEC.

The statistical procedure included the following steps:

(1) the students were assigned to the pre/post intervention groups randomly.
(2) the data were tested for equal variance. All compared sets were found to be equal in variance.
(3) the data sets have been then evaluated for normality utilizing the Shapiro-Wilk test [18].

Six out of the sixteen sets were found to be not normally distributed. Comparison among non- normal distributed sets and comparison between hybrid sets (one set is normally distributed and the other is not) have been done with the Mann-Whitney-U non-parametric tests [19] and with parametric t-tests. For all of these sets the results of the Mann-Whitney-U non-parametric test and the parametric t-test (single tail for both tests) revealed the same results.

The tests above were used to accept/reject the hypotheses. It was expected that the weights of dimensions other than safety and their respective search indices will decrease to accommodate an increase in weight for safety and increase in SSI.

A shift in final choice selection was expected toward alternatives with the highest evaluation on safety as a decision dimension.

3. Results

The project was deployed during Fall 2009. The senior design class included 28 students (three females, 25 males) from ABE at ISU. All participants were traditional age students (younger than thirty years old); however, information on exact age was not collected.

The class was introduced with the project's objectives and process during class meeting time. At the end of the meeting, user IDs were distributed to approximately half of the class (15 students, Pre-treatment group). The pre-treatment group was given a week to take the decision making simulation. Students could take the simulation on any computer terminal with internet access. The simulation took 5–10 minutes to complete.

Upon completion of the simulation by the entire pre-treatment group, the content of SAEC was "released" to the students through WebCT. The students were given four weeks to complete the SAEC module. At the end of the four week period, the other half of the class (13 students) was asked to take the decision-making simulation (post-treatment group).

Only two students did not complete all seven assessment modules. One of these students missed two of the assessments due to personal issues. Another student did not complete the seventh assessment. The calculated mean grade for all assessments was 69.7 (on a scale of 100) with a standard deviation of 12.3.

Results of the analysis of the decision making simulation are given below. Table 1 presents the means (μ), standard deviations (σ), standard errors (S.E.), and the level of significance (p) from the significance test for the weights assigned by the pre and post treatment group members.

Similarly, Table 2 presents the means (μ), standard deviations (σ), standard errors (S.E.), and the level of significance (p) for the Search Indices SSI,

Table 1. Results of analysis of weights

	Safety			**Capacity**			**Hygiene**			**Instruments**		
	Pre	**Post**	***p***	**Pre**	**Post**	***p***	**Pre**	**Post**	***p***	**Pre**	**Post**	***p***
μ	26.07	33.92	0.0131	22.27	23.54	0.2886	29.13	23.85	0.0511	22.67	19.00	0.0481
σ	8.48	9.14		6.62	5.11		5.85	9.68		6.19	5.53	
S.E.	2.19	2.50		1.71	1.42		1.51	2.69		1.71	1.26	
N	15	13		15	13		15	13		15	13	

(Criterion for significance: $\alpha = 0.05$)

Table 2. Results of analysis of search indices

	SSI			**CSI**			**HSI**			**ISI**		
	Pre	**Post**	***p***	**Pre**	**Post**	***p***	**Pre**	**Post**	***p***	**Pre**	**Post**	***p***
μ	1.079	1.537	0.0404	1.178	0.889	0.0901	1.183	0.868	0.0962	0.695	0.779	0.2981
σ	0.527	0.798		0.716	0.359		0.721	0.519		0.292	0.493	
S.E.	0.136	0.221		0.185	0.100		0.186	0.144		0.075	0.137	
N	15	13		15	13		15	13		15	13	

(Criterion for significance: $\alpha = 0.05$)

Table 3. Distribution of final choice

Choice	Pre-treatment	Post treatment
A	11	11
B	0	0
C	4	2
D	0	0

CSI, HIS, and ISI (calculated based on equations 1, 2, 3, and,4, respectively) from the significance test for the pre and post treatment groups.

4. Discussion

Weights of dimensions represent the perception the subjects have on the relative importance of a dimension with respect to the other dimensions in the decision task. The average of weights *Safety* was assigned as a decision dimension increased by approximately 30% between the pre- and post-treatment groups. This increase was statistically significant, from μ=26.07 to μ=33.92 (*p=0.0131*). This significant increase in weight for Safet*y* led to a noticeable change in Hygiene and Instrumentation. Hygiene experienced a (almost) significant decrease of 18.2%, from μ=22.27 to μ=23.85 (*p=0.051)* and so did Instrumentation, which decreased by 15.9%, from μ=22.67 to μ=19.00 (*p=0.048*). The average weight of Capacit*y* did not changed significantly (μ=22.27 to μ=23.54, *p=0.288*).

As mentioned above, the dimension search indices represent the level of emphasis the subjects put on a dimension with respect to the emphasis they placed on the other dimensions during the information search. The following section provides interpretation for these indices: A dimension search index with a value of "1" indicates that the specific dimension did not get a priority nor was it ignored during the information search. A value of "0" indicates that no information was searched in this dimension (i.e., the dimension was completely ignored in the judgment process). A value of "2" indicates that, on average, the amount of information reviewed on this specific dimension was twice the average of the amount of information that was searched on the other dimensions.

A comparison of the values of SSI with a hypothetical value of "1" revealed that the SSIs for the pre treatment group was insignificantly different from "1" (*p=0.6325*); i.e. the pre- treatment group did not prioritize Safet*y* as a decision dimension with respect to the other dimensions. However, the results in Table 2 indicate that, on average, the post-treatment group reviewed 42.4% more information on Safety than the pre-treatment group (SSI grew from μ=1.079 to μ=1.537, *p=0.0404*). This shift in SSI indicates a significantly higher emphasis on Safety by the post-treatment group.

A review of shifts in CSI (μ=1.178 to μ=0.889, *p=0.0901*), HSI (μ=1.183 to μ=0.868, *p=0.0962*), and ISI ((μ=0.695 to μ=0.779, *p=0.2981*) reveal that no specific dimensions were "scarified" to allow the increase of Safety as a prioritized dimension in the information processing. A comparison of shifts in weights demonstrates that Safety was the only dimension demonstrating significant positive shift.

In summary, both hypotheses, **H1** and **H2** have been accepted.

Final decision: the four alternatives in the decision scenario were four prototype systems (A, B, C, and D) for preparing fast food. Among these four prototypes, Safety is the only dimension on which prototypes B and D have had negative evaluations. These two prototypes were not selected as a final choice, suggesting that the subjects utilized Safety as a non-compensatory decision dimension, eliminating alternatives that did not pass their minimum threshold on this dimension.

The evaluations of the remaining two alternatives, prototypes A and C, on *Safety,* read as follows:

- Prototype A: "This model is well designed to address general safety aspects associated with cooking activities. It could be improved however, by incorporating safety features that prevent the development of wrist and back injuries."
- Prototype C: "This prototype consists of a variety of safety elements that address issues such as protecting the operators from oil burns, preventing ergonomic aspects associated with lifting heavy items, etc."

Although prototype C is evaluated slightly higher on Safety, prototype A is evaluated significantly higher on Capacity and Hygiene making this prototype superior to C, thus, explaining the overwhelming selection of A as a final choice by both groups.

5. Conclusions

An autonomous on-line safety awareness-enhancing curriculum (SAEC) was developed to increase safety awareness in engineering students. A decision making simulation was utilized to assess the effectiveness of the SAEC in increasing awareness among students. The results indicated a significant increase in safety awareness following implementation of SAEC. It is important to emphasize that the study is based on a limited number of subjects. Therefore, the data were analyzed carefully with an appropriate statistical procedure.

The study emphasizes the advantage associated with utilizing a decision making simulation for the assessment in comparison to using perceptions-based evaluation. As presented in the Discussion section, the decision making simulation provides more insights on the effect of the intervention by not only measuring shifts in awareness but also understanding the cognitive processes associated with these shifts.

It is important to note that the study is limited in its ability to predict whether the module will produce a noticeable effect in the workplace. When students enter the workplace they are subjected to a "contamination" by the safety climate and culture at the workplace. However, it is expected that the increase in safety awareness will yield eventually to a positive shift in safety culture. The research team works with the industry to examine the effect of safety climate on safety awareness (e.g., [11]). The team examines the opportunity of developing a longitudinal study for measuring the magnitude of impact SAEC produces at the workplace.

Another concern is the low average grades students acquired in the SAEC. This average indicates somewhat low knowledge gain. A review of the Plus/Delta session suggests that the content was well prepared and delivered, and provided appropriate opportunity to accomplish the learning objectives. To avoid low knowledge gain, future SAEC sessions will include an Ongoing Feedback-Based Assessment (OFBA) algorithm that will not allow progression to the next sub-module until satisfactory results are achieved in the current module. As part of the continuous effort to increase students' competencies in the CoE at ISU, significant resources are invested in the assessment of competencies during experiential education activities. Assessment includes the rating of competencies by students and their internship/cooperative education supervisors, an extensive and long process. The implementation of the assessment approach herein for assessment of safety awareness requires little effort on behalf of the faculty and can provide results immediately after completion of the program.

Future research and development will concentrate on the following items:

- Automating the decision making simulation to a system that provides assessment instantaneously;
- Involve students across all engineering disciplines in the use of the SAEC and the simulation system;
- Development of a library of simulations for other competencies;
- Provide other schools with the opportunity to use the SAEC and the simulation system.

References

1. NSPE Code of Ethics for Engineers, http://www.nspe.org/Ethics/CodeofEthics/index.html (Accessed 23 December 2010).
2. L. F. Hanneman, S. K. Mickelson, L. K. Pringnitz and M. Lehman, Constituent-created, competency-based, ABET-aligned assessment tools for the engineering experiential education workplace, *2nd ABET National Conf. Outcomes and Assessment for Program Improvement,* Pittsburgh, Pennsylvania, 2002.
3. T. J. Brumm, L. F. Hanneman and S. K. Mickelson, Assessing and developing program outcomes through workplace competencies. *International Journal of Engineering Education*, **22**(1), 2006, pp. 123–129.
4. T. J. Brumm, S. K. Mickelson, B. L. Steward and A. L. Kaleita-Forbes. Competency-based outcomes assessment for agricultural engineering programs. *International Journal of Engineering Education*, **22**(6), 2006, pp. 1163–1172.
5. S. K. Mickelson, P. C. Harms, and T. J. Brumm, Longitudinal study of learning communities in agricultural and biosystems engineering. *International Journal of Engineering Education*, **23**(4), 2007, pp. 672–682.
6. S. M. Dillon, Descriptive Decision Making: Comparing Theory with Practice. *Proceeding of the 33rd Annual Conference of the New Zealand Operational Research Society*, New Zealand, 1998, pp. 99–108.
7. J. G. March and J. P. Olsen, Garbage Can Models of Decision Making in Organizations, in March, K.G. & Weissinger-Baylon, R. (Eds), *Ambiguity and Command*, 1996, Longman Inc, USA, pp. 11–35.
8. J. W. Payne, J. R. Bettman, and E. M. Johnson, *The Adaptive Decision Maker*. Cambridge: Cambridge University Press. 1993.
9. A. Newell and H.A. *Human Problem Solving*. Englewood Cliffs, NJ: Prentice-Hall. 1972.
10. A. Tversky, Elimination by aspects: a theory of choice, *Psychological Review,* **79**, 1972, pp. 281–299.
11. N. Keren, T. R. Mills, S. A. Freeman and M. C. Shelley, Can level of safety climate predict level of orientation toward safety in a decision making task? *Safety Science,* **47**(10), 2009, pp. 1312–1323.
12. L. Helminski and S. Koberna, Total quality in instruction: A systems approach. In H. V. Roberts (Ed.), *Academic initiatives in total quality for higher education,* Milwaukee, WI, 1995, pp. 309–362.
13. SimSolution Decision Making Optimized, http://www.itgitraining.com/aboutus.asp (Accessed 23 December 2010).
14. R. S., Billings and L. L. Scherer, The effects of response mode and importance on decision-making strategies: Judgment versus choice, *Organizational Behavior and Human Decision Processes*, **41**, 1998, pp. 1–19.
15. A. Mintz, How Do Leaders Make Decisions? A Poliheuristic Perspective. *Journal of Conflict Resolution*, **48**(1), 2004, pp. 3–13.
16. A. Mintz, Are leaders susceptible to negative political advice?: An experimental study of high-ranking military officers. In A. Mintz & B. Russett (Eds.), *New Directions for International Relations,* Lahman, MD, Lexington Books 2005.
17. A. Mintz and N. Geva, The Poliheuristic Theory of Foreign Policy Decision Making, In Decision-Making on War and Peace: The Cognitive Rational Debate, In N. Geva & A. Mintz, Boulder CO, 1997.
18. Shapiro, S. S. and Wilk, M. B. Analysis of variance test for normality (complete samples), *Biometrika*, **52,** 1965, pp. 591–611.
19. M. Hollander and D. A. Wolfe, *Nonparametric Statistical Methods* (3rd Ed.). NY: Wiley-Interscience Pub. 1999.

Appendix A: Decision matrix

	Alternatives			
	Prototype A	**Prototype B**	**Prototype C**	**Prototype D**
Hygiene	Prototype A is assembled from large parts; thus, an acceptable level of hygiene can be achieved with minimal efforts	A creative design that includes self cleaning features. Efforts include only loading detergent and emptying waste	This design includes a large number of assemblies, sub-assemblies, and parts. Cleaning this prototype requires some significant efforts	While cleaning is not too much of a hurdle, the design of this prototype could be improved to reduce the efforts required to achieve appropriate level of hygiene
Capacity	A modular design that allows adding further units to meet every level of demand	With some design adjustments, this module can be converted to modular units that can meet every level of demand	This prototype was design with a complex piping system. The results of the analysis indicate a capacity to of approximately 100 servings per hour	With some design adjustments, this module can be converted to modular units that can meet every level of demand
Safety	This model is well designed to address general safety aspects associated with cooking activities. It could be improved however, by incorporating safety features that prevent the development of wrist and back injuries	The design did not appropriately address safety issues associated with preventing the operators from getting oil burns when soaking frozen food items in hot oil	This prototype consists of a variety of safety elements that addresses issues such as protecting the operators from oil burns, preventing ergonomic aspects associated with lifting heavy items, etc.	The design is missing common safety related instruments such as warnings when: opening covers when oil is hot, microwave is at work, hot surfaces, etc.
Instrume- -ntation	The design uses sufficient automated controls to verify appropriate food quality. However, it lacks audio and visual announcements to inform operators when food processing/cooking is complete	Due to the self cleaning feature, this design is comprised with significant instrumentation that increases the frequency of maintenance and the need to incorporate intensive preventive maintenance procedures	This prototype does not include sufficient controls and indications on cooking parameters. Thus, the system's operator will be required to pay attention to food quality while it is processed	An optimal instrumentation design that introduces a balance between the need for automation and the need to maintain automation components

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