AC 2007-691: A DEPARTMENTAL REFORM STRATEGY AND THE RESULTANT NATIONAL MODEL FOR AN UNDERGRADUATE INDUSTRIAL ENGINEERING CURRICULUM

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A Departmental Reform Strategy and the Resultant National Model for an Industrial Engineering Undergraduate Curriculum

Abstract

This paper presents the results of an extensive research study to develop a national model for an undergraduate curriculum in Industrial Engineering. A departmental reform strategy was developed and applied to reengineer the IE curriculum. The reform strategy began with identifying the voice of the customer, including both industry and academic institutions which employ or enroll IE students after they graduate with their IE undergraduate degree. The emerging topics and desired characteristics of undergraduate IE graduates were identified in an earlier research study. These emerging topics were used in a focus group to identify high-level knowledge clusters of information that future IE graduates would need to master based on possible future work scenarios. The emerging topics were mapped to the high level knowledge clusters to generate curriculum requirements of future progress. This research effort developed a revised IE curriculum that can be used as a national model for IE departments. This curriculum focuses on nontraditional industry sectors, incorporating enhanced instructional strategies that can improve learning and retention, as well as state-of-the art technologies that support these strategies. The national model also includes material to help engineers gain knowledge that will help to prepare them for roles of leadership and management in their careers, as well as provides for recruiting strategies to increase the numbers of underrepresented minorities and women in IE programs. This paper describes the approach used in this research effort to develop the national model, as well as details of the resulting model for undergraduate IE curriculum.

Introduction

The Industrial Engineering and Management Systems department at the University of Central Florida with its Industrial Advisory Board designed a comprehensive multi-faceted three-year plan to reengineer the Undergraduate Education Program. The effort involves making significant changes in the curriculum, developing aggressive recruiting strategies to attract students into the Industrial Engineering profession, transforming faculty instructional strategies, and introducing new technology in the classrooms while providing additional experiential opportunities for students. The IE undergraduate national model was developed as a result of the efforts pursued during the National Science Foundation (NSF) Implementation Grant for Departmental Reform that was awarded in 2003.

This paper described the departmental reform strategy developed and applied to create the national model, as well as the national model generated to the IE undergraduate curriculum of the future.

Research Goal

The Goal of this research activity was to implement a comprehensive Departmental Reform strategy that will serve as a national model for other departments interested in significantly

altering the number of Industrial Engineering graduates who are prepared for careers in the newly changing types of industries (i.e. non manufacturing, service, information technology, etc.) and the many roles of management and leadership that engineers are expected to perform within these industries.

Research Objectives

The specific research objectives chartered to achieve the stated research goals include:

• Reengineering of the Curriculum to include course work that better prepares students for careers in nontraditional manufacturing industries (ie. service industries, information technology industries, as well as job positions and role responsibilities in engineering management and leadership.)

• Integrate Cognitive Learning Theory and Instructional Design Theories that will provide experiential learning and student experiences in the classroom.

• Integrate Cognitive Learning Theory and Instructional Design Theory to identify appropriate uses of technology to support classroom instruction goals and student learning objectives.

• Develop aggressive recruiting strategies that increase awareness of IE careers among High School students and serve to entice them to pursue Industrial Engineering with special emphasis upon exposing members of historically underrepresented groups and females.

The project has contributed to engineering education in two major ways: 1) to provide a strategy that other departments of higher education can use to reform their curriculum; and 2) provide a national model that other IE departments can use to educate industrial engineers in the evolving global economy.

National Model Curriculum Development Methodology

Departmental Reform activities are very complex in nature and can be overwhelming thus, it is critical to have a well documented and developed strategy for pursuing departmental reform activities. The following graphic (figure 1) shows the departmental reform strategy that the research team has used to reengineer the IE curriculum. This strategy is robust enough to allow other departments and disciplines to apply the same strategy when reforming their curriculum.

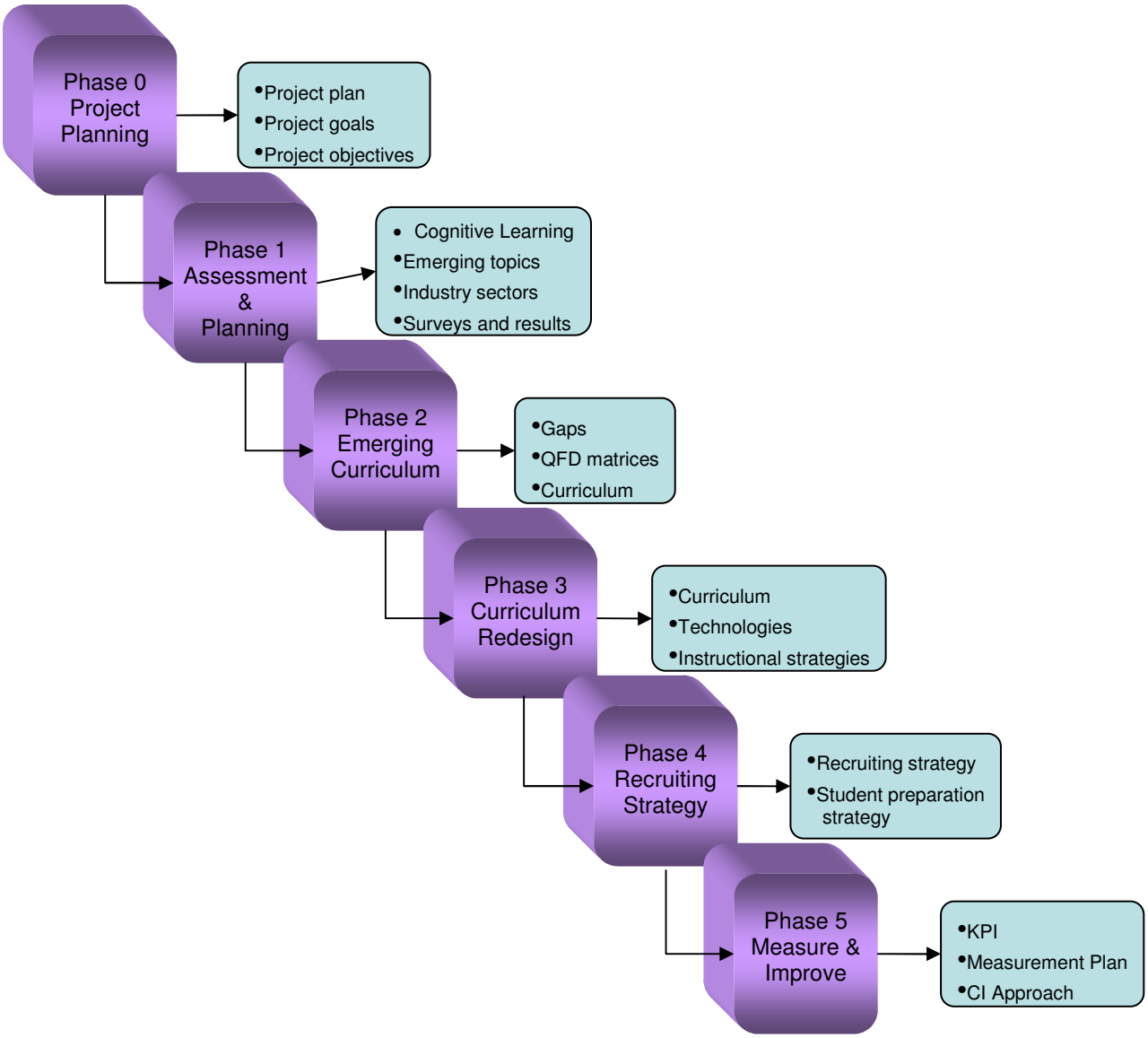

Figure 1 Departmental Reform Strategy

1.1 Phase 0 Project Planning

The objective of Phase 0 was to define the project objectives, the project approach, obtain buy-in from the department's Industrial Advisory Board, and obtain funding. Funding was obtained from the National Science Foundation (NSF) as part of the Departmental Level Reform Program in 2002 to develop and evaluate the Departmental Reform Strategy that could be used to successfully guide the efforts and activities to revise the curriculum with the department.

1.2 Phase 1 Assess Current State of Industry and Industrial Engineering Curriculum

The objectives of Phase 1 were to assess the current state of the industry to identify emerging topic areas that would be beneficial to future IE graduates and to benchmark the existing

industrial engineering curriculum. The first major activity was to identify emerging topics and non-traditional industry sectors through a literature review and through surveying the industrial sector. The Delphi technique was used to survey the academic and industrial sectors where Industrial Engineers are educated and was employed to identify the key emerging topics. Many researchers have used different variations of the Delphi technique in the last decade to rank and rate the relative importance of the desired attributes and characteristics of university graduates [8] to identify the competent curriculum contents and topics for undergraduate and graduate education program [4] [5] [6] and even both [7]. Three Delphi rounds were performed to 1) identify the emerging topic areas, 2) assign emerging topic importance, and 3) obtain consensus on the emerging topics. [1]

Also within this phase, the team benchmarked against major universities to understand the courses offered at the top three undergraduate IE departments and three additional top undergraduate IE departments. The goal of this research activity was to identify how the benchmarked departments currently support the emerging topics identified during the Delphi survey activities.

1.3 Phase 2 Identify Emerging IE Curriculum Requirements

The objective of Phase 2 was to develop the IE curriculum requirements based on the identified emerging topic areas that were found to be critical to future IE graduates. Quality Function Deployment (QFD) was used to ensure that the reengineered IE curriculum meets the customer requirements, as well as accreditation standards. QFD is a management technique that is used to organize and map the customer requirements to technical requirements and to capture the Voice of the Customer or the customers' requirements. [2] A critical component of the departmental reform strategy has been to link the emerging topics (knowledge) to the desired characteristics of the customers who employ or receive our students as students in higher education as the voice of the customer. The knowledge was then used to create the curriculum requirements for the reengineered curriculum that would be needed to ensure future graduates possess the desired set of knowledge, preparation and skill sets. The Quality Function Deployment (House of Quality) used in this research in Figure 2 shows the linkages.

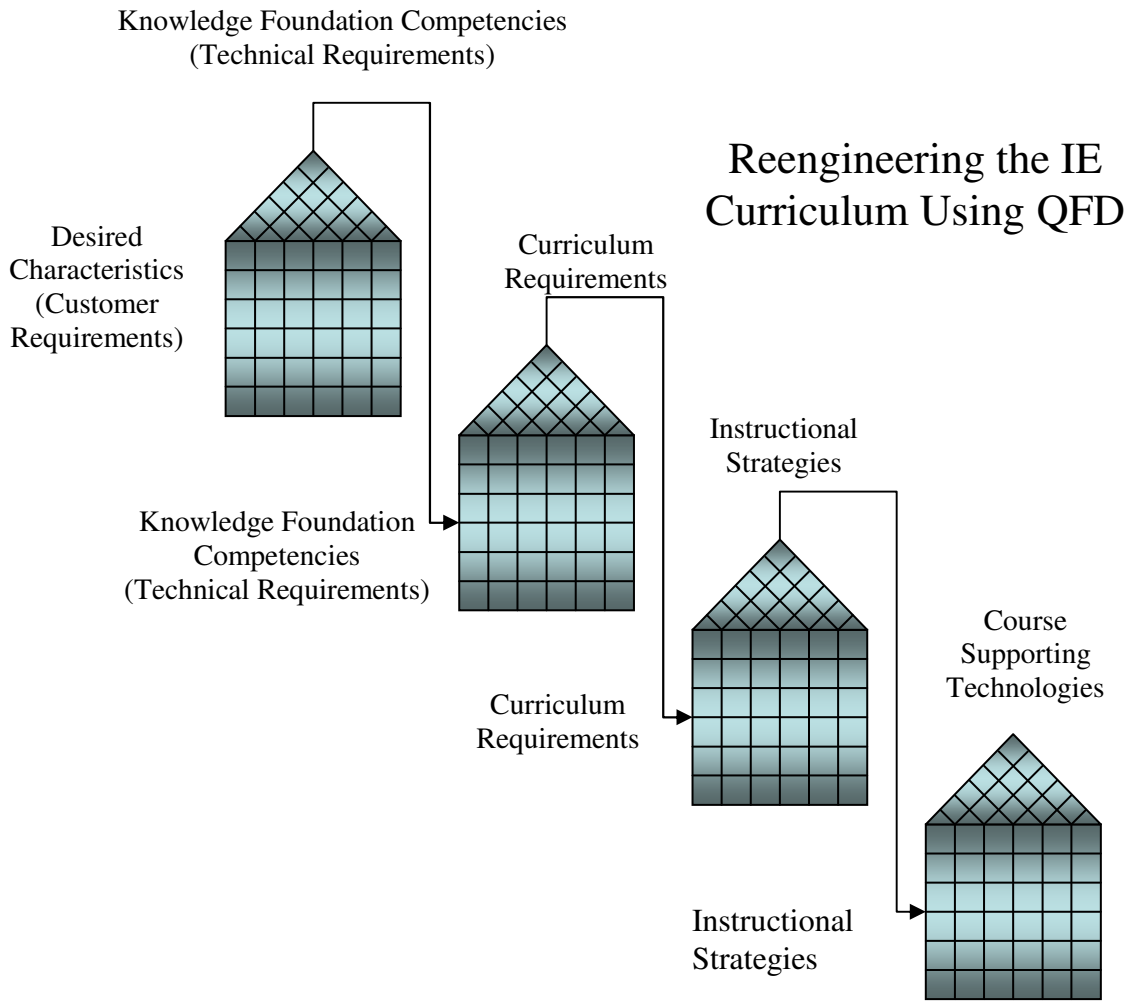

Figure 2 QFD Matrices describing Strategy used to Re-engineer IE Curriculum

The second step of the process to identify emerging IE curriculum requirements was to conduct a Focus Group session. The Focus Group process consisted of:

A) Reading three scenarios of expected engineering situations within industrial settings. The three scenarios were entitled:
   - i) The Aerospace Industry of the 21st Century
   - ii) Applying Industrial Engineering Concepts and Techniques to Improve Health Care Service Delivery
   - iii) Portable Personal Entertainment System (PPES): Leading the Wireless Industry Future

B) Gathering participant's comments and feedback using the scenarios wherein the participants identified concepts that "tomorrow's" Industrial Engineers will be expected to address in their business / engineering roles.

C) Identifying clusters or themes by which to organize the concepts into potential areas of study with the curriculum.

D) Ranking the future Desired Characteristics expected from an Industrial Engineer, using the characteristics developed from the earlier survey work.[1] The participants were asked to rate each of the desired characteristics using the following scale:

   i) High Importance
   ii) Medium Importance
   iii) Low Importance

E) Ranking the Emerging Topics to be covered in "tomorrow's" Industrial Engineering curriculum by order of importance, using the topics developed from the earlier survey work.

F) Identifying any other characteristics or emerging topics that they believed should be added to the list created from the survey results.

The focus group session was held at the national Institute of Industrial Engineers Research Conference in Orlando, Florida, with academic and industry participants, including in departmental advisory board members. Industry organizations were selected from the UCF IEMS departments Industry Advisory Board who employ extensive number of Industrial Engineers, and who provide guidance in continuously improving our curriculum, and who are key stakeholders for this curriculum redesign study. The organizations include: Disney, NAVAIR, General Motors, EuroScandia Enterprises and SAIC. Academic Institutions were selected from a broad list of universities with IE departments, and other universities that have engaged in curriculum redesign efforts over the last several years. The academic participants included current or former department chairs and faculty who have been heavily involved in engineering education and/or curriculum reform. The academic institutions include: University of San Diego, Wayne State University, University of Florida, UT Knoxville, University of South Florida, University of Central Florida, Ohio State University, Tennessee Technological University, Univ del Turabo.

The focus group participants prioritized the emerging topics and desired characteristics based on the future scenarios described in the earlier sections. Next, the focus group developed high level Industrial Engineering knowledge clusters based on the three scenarios of expected future conditions in the business world, including: 1) the aerospace industry of the 21st century (with a focus on system of systems); 2) applying industrial engineering concepts and techniques to improve health care service delivery; and 3) portable personal entertainment systems (PPES): leading the wireless industry future. After the focus group, the research team grouped the emerging topics into the clusters, and the focus group participants validated the groupings.

IE Knowledge Clusters

Following are the high level topic clusters that represent the desired IE knowledge base of future graduates, and the main concepts to be taught in an IE undergraduate curriculum. The following table includes a description of the desired IE knowledge clusters and their corresponding IE concepts and Emerging topics.

Table 1 IE Knowledge Clusters, Concepts and Emerging Topics Mapping

IE Knowledge Cluster	Cluster Description	IE Concepts to be taught	Emerging Topics
Cluster 1: Global Perspectives:	This cluster represents the capability of the IE to incorporate into his/her thinking and decision process an understanding of the globalization of commerce, industries, organizations, etc.	• Transnational cultures • Global competitiveness • Global collaboration • Global politics • Security of intellectual property, patents, etc. • Communications, differences in communication styles and methods from culture to culture • Data exchange, knowing what governmental restrictions exist that limit the exchange of information • Safety and security, the different personal security precautions that must be taken within various environments and countries	• Lean Enterprise • Six Sigma • Enterprise Resource Management • Benchmarking • Customer Relationship Management • Agile Manufacturing
Cluster 2: Technologies	This cluster represents the capability of the IE to understand the latest in information, modeling, communications, and industrial applications technologies and apply this understanding to his/her decision making process.	• Product data management • Communications • Data exchange • Software development and engineering • Probability and optimization • Life cycle (product and services)	• Statistical Methods for Services and transaction entities • Ergonomics • Human Integrated Systems / Usability • Object Oriented Simulation

IE Knowledge Cluster	Cluster Description	IE Concepts to be taught	Emerging Topics
		management • Emerging technologies • New product introduction	• Multiple Objective Optimization
Cluster 3: Value	This cluster represents the capability of the IE to understand the value effect of his/her decisions and actions. The IE evaluates opportunities and risks from the point of view of what value is provided to the external customer, and what value is gained by his/her organization.	• Voice of the customer • Life cycle / total value stream analysis • Risk management • Business case development • Feedback systems to evaluate and monitor value • Market dynamics, which affect ongoing real and perceived value • Costs (of products, services, support, etc.) • Voice of the stakeholders	• Ethical Behavior • Performance Management
Cluster 4: Financial Management	This cluster represents the capability of the IE to understand the financial aspects of the organization, and the financial impacts of his/her processes and decisions.	• Revenues and costs (understanding what drives these) • Financial modeling / simulations • Forecasting • Investments (in equipment, research, market knowledge, etc.) • Sources of financing • Product life cycle (revenues, costs, margins, and especially those associated with the "sunset" phase of the life cycle)	• Financial Engineering

IE Knowledge Cluster	Cluster Description	IE Concepts to be taught	Emerging Topics
		• Supply chain costs • Intellectual property costs (and costs to protect IP)	
Cluster 5: Total Systems Thinking	This cluster represents the capability of the IE to recognize context, relationships, influences, etc. that will impact his/her decision making process, as well as to predict the impacts of decisions beyond the immediate issue. It includes the capability of the IE to understand the entire suite of "systems" within the organization, their interaction with each other, and their interaction in supporting a global view of the market.	• Virtual enterprise • Enterprise integration • Optimization • Strategy • Corporate culture • Security (information and design) • Understanding the legal and market environments • Resource management • Process management • Supply chain management • Logistics systems management • Customer relationship management • Globalization, in the context of using the above systems to support global capabilities	• Leadership • Team Building and Facilitation • Service enterprise • Organizational Behavior
Cluster 6: Information Systems	This cluster represents the capability of the IE to understand the latest capabilities and technologies of Information Systems used for managing business issues and information.	• Database management • Information security / privacy • Information exchange: real time, documents, collaboration, etc.	• Human Computer Interface • Knowledge Management
Cluster 7: New Product Development	This cluster represents the capability of the IE to understand all the conceptual variables	• Security (of design, intellectual property, patents) • Rapid prototyping	• Project Management • Design for Six Sigma

IE Knowledge Cluster	Cluster Description	IE Concepts to be taught	Emerging Topics
	that affect the new product development process, and to be a strong contributor to the new product development process.	• Project management • Design (e.g., Design for Manufacturability / Assembly) • Software development • Value / value management of the product / services • Social demographics • Partnerships (with design collaborators, suppliers, researchers) • Product life cycle management • Interoperability (how the new product / service interoperates with other advances in the market)	• Time to Market • New Product Development

IE Model Curriculum

These clusters were then used to develop a model curriculum for an IE undergraduate program. The curriculum will consist of an eight-hour mega course, several advanced courses, and a culminating capstone experience. The mega course provides an overview of computer programming, databases and information systems and the basic concepts and tools of industrial engineering. The rationale for the mega course is to tie the key technologies and IE concepts together and provide a broad stroke and high level map of the advanced IE courses that the students will take during their senior year of the curriculum. However, mega courses have faced some resistance in practical application due to the risk to the students' academic standing if they do poorly in one course that counts for 8 credit hours. Therefore, the research team will further investigate and research the feasibility of implementing the 8-hour mega course, or breaking it into two or three smaller courses.

A) <u>Mega Course Content (8 Hours):</u>

- Computer Programming
- Databases and Information Systems
- Overview Course (2 hours) - To provide an overview of design and process related issues to the operation of an industrial or service facility. Students will understand the various IE skills they will need as industrial engineers.

B) Advanced Courses: (3 credit hours each, total of 42 hours)

The advanced courses provide more detailed knowledge of IE concepts and tools.

- Productivity improvement, design of processes, lean enterprise, agile manufacturing
- Quality assurance, quality management, quality engineering, including six sigma, benchmarking
- Enterprise Resource Management, Customer Relationship Management
- Statistical Methods for Industrial Engineering
- Ergonomics, Human Integrated Systems / Usability, Human Computer Interface
- Object Oriented Simulation
- Performance Management
- Financial Engineering
- Leadership, Team Building & Facilitation, Organizational Behavior
- Operations Research
- Project Management
- Service Enterprise
- Knowledge Management
- Design for Six Sigma, New Product Development

C) Experiential Learning Capstone (6 hours)

The senior design experience will be a two-semester, hands-on, project-based experienced with industry that provides the students with an opportunity to synthesize and apply the IE tools and concepts learned throughout the curriculum.

- Senior Design 1
- Senior Design 2

Ethical Behavior will be incorporated as case modules across the advanced courses in the curriculum, mapped to appropriate IE specific topic areas.

The research teams' website www.ieeducation.us can be accessed to view the course objectives developed for each course. Also detailed course syllabi are currently being developed and will be accessible on the website.

Future Work

The research team is developing the curriculum course objectives, instructional strategies that will enhance learning of the revised curriculum, and technologies that will support the courses. The research team has communicated the findings to the UCF IEMS faculty throughout the project, to obtain their input and gain their support and commitment to the enhanced curriculum, with the goal of implementing the reengineered curriculum into the undergraduate IE curriculum in the future. To this point, the faculty has been receptive to the emerging topics that have been

identified, and want to be a part of the discussions into how they will be incorporated into the existing courses and current topics. Workshops will be developed so that the faculty will learn the enhanced instructional strategies that will enhance learning and retention of material. It is anticipated that the pre-requisites requirements may change as the emerging topics are incorporated into existing courses and new courses are developed and incorporated into the existing curriculum. It is anticipated that the qualifications of the incoming students would not need to change, but that the outcomes of the students will be enhanced through the redesigned curriculum.

Summary and Conclusions

This paper presents the results of a research study conducted to develop a national model for an undergraduate IE curriculum. The results of this study are useful to other departments. Also these results are useful to other disciplines in higher education that can apply the departmental reform strategy to reform their curriculum, as undergraduate IE departments across the nation. The findings provide a strategic look into the future of IEs and how IE programs can adapt to better prepare their graduates to meet the future challenge of working in a rapidly changing global work environment.

This study will be further extended to develop detailed course objectives and topics, as well as incorporate enhanced instructional strategies into the IE curriculum to improve students' learning and retention of the materials taught in IE programs.

Acknowledgements

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