The Design and Implementation of an Advanced Analytics Laboratory Supporting Industry Partnerships

Emory Zimmers, Charalambos Marangos

Professor, Industrial and Systems Engineering, Director, Enterprise Systems Center, Lehigh University/President, Zephyros, Inc., Consultant, Advanced Analytics Laboratory

Abstract

The objective of this paper is to describe the design, implementation and utilization of the Advanced Analytics Laboratory within the Enterprise Systems Center (ESC) at Lehigh University. This new capability is supported by many industry partners and Lehigh alumni, and has received needed resources and encouragement from the SAS Institute. The Laboratory has facilitated additional company partnerships and provided significantly enhanced project-based learning experiences for undergraduate and graduate students. This paper includes examples that describe how Lehigh's Industrial and Systems Engineering Department works in cooperation with the Advanced Analytics Laboratory to incorporate real-world project learning within the curriculum.

The physical facilities of the Advanced Analytics Laboratory have three major components. One is an open concept Analytics Research and Industry Project Work Area where all levels of participants freely interact. The second is a Project Work Station and Instructional Development Area. This space is used to design and rapidly pilot new educational content as well as provide resources to support project-oriented student work. The third component is the Collaboratory, which is being upgraded to support remote conferencing, student project presentations, and industry interactions for a range of student group sizes, from small to class size.

As a central part of its operation, Advanced Analytics Laboratory personnel maintain close contact with partner companies to provide students with projects, internships, and research opportunities. This paper explains operational models currently used as well as approaches planned for the future. For example, the Laboratory employs a system of "layered mentoring," utilizing relationship managers from the Enterprise Systems Center, industry partners, as well as faculty, to give teams of undergraduate and graduate students well-rounded practical and rigorous theoretical guidance on the application of advanced analytics techniques. An example is provided to illustrate this approach.

Further, the paper outlines the approach being taken to incorporate "student outcomes" input into a continuous improvement process. In the final section future initiatives are presented. These include an Analytics Minor, a university-wide Collaborative Analytics Forum and coupling analytics techniques with an existing portfolio of leadership development programs hosted or sponsored by the Advanced Analytics Laboratory.

Background on the Advanced Analytics Laboratory and Enterprise Systems Center

The Advanced Analytics Laboratory was established in 2013 to support realistic learning experiences in the field of analytics. This is accomplished by utilizing existing software tools and techniques, and where appropriate, developing new ones. In addition, maintaining a strong collaborative relationship with industry and government partners is an important component of the Advanced Analytics Laboratory's mission. The Advanced Analytics Laboratory's administrative support and physical location is within Lehigh University's Enterprise Systems Center.

The Enterprise Systems Center (ESC) is designated as a Lehigh University Complex Engineering Systems Research Center in the P.C. Rossin College of Engineering and Applied Science. From its early years as the Computer Integrated Manufacturing (CIM) Laboratory, the ESC has evolved to a center of excellence in enterprise systems engineering. Collaborative projects with industry are often structured to include analysis, design, and systems implementation support required in today's competitive global environment. Because of the multidisciplinary nature of many industry engagements, technical areas such as operations research, analytics, supply chain and logistics, management science, product innovation, sustainability, and agile manufacturing are often a part of industry projects. However, in the past several years, the utilization of analytics tools and techniques has taken on an increasingly central role in project activity. Recognition of this trend was an important factor in the decision to establish the Advanced Analytics Laboratory.

Industry projects support a common Enterprise Systems Center and Advanced Analytics Laboratory mission, which is to help students increase their technical expertise, hone leadership skills, and improve their ability to conceptualize and solve unstructured and multidisciplinary problems in a real life setting. Students engage with professors, mentors, consultants, subject matter experts, and industry partners, all of whom provide guidance. This approach helps to ensure the success of a given project while preparing students to become effective and innovative practicing engineers.

Since its inception, the ESC has completed more than 1,100 research and development projects with over 425 industry partners. More than 3,000 undergraduate and graduate students from the engineering, business, and arts/science colleges have participated on interdisciplinary teams to achieve high return on investment deliverables. Students with Center experience report a perceived advantage when interviewing with corporate recruiters and ultimately in their career growth. Approximately 95 student participants – 80 percent undergraduate and the remainder graduate students – complete industrial projects working with the Enterprise Systems Center every year.

Prior to the establishment of the Advanced Analytics Laboratory, which was encouraged by industry partners and especially the SAS Institute research programs conducted by the Enterprise Systems Center have included several with the National Science Foundation, the Department of Defense, and the Pennsylvania Department of Community and Economic Development. Additionally, many research programs have been conducted jointly with industry including the IBM Thomas Watson Research Center.

Finally, it is important to note that many of the Center's programs, especially those connected to the Advanced Analytics Laboratory, are linked to a partnership with Lehigh's Department of Industrial and System Engineering (ISE). Anecdotal evidence indicates that laboratory-oriented programs are having a positive intellectual impact on student development and overall career preparation.

Design Features of the Advanced Analytics Laboratory

The design of the Laboratory's physical facilities has relied on input from the following groups: industry partners, participating faculty (primarily in the Department of Industrial and Systems Engineering), project mentors, and consultants (especially those associated with the Enterprise Systems Center). Undergraduate and graduate students working on industry projects with the Center have provided input to the design process and have been welcomed as important stakeholders.

The physical layout of the Enterprise Systems Center and Advanced Analytics Laboratory is comprised of three physical facility components as shown in Figure 1.

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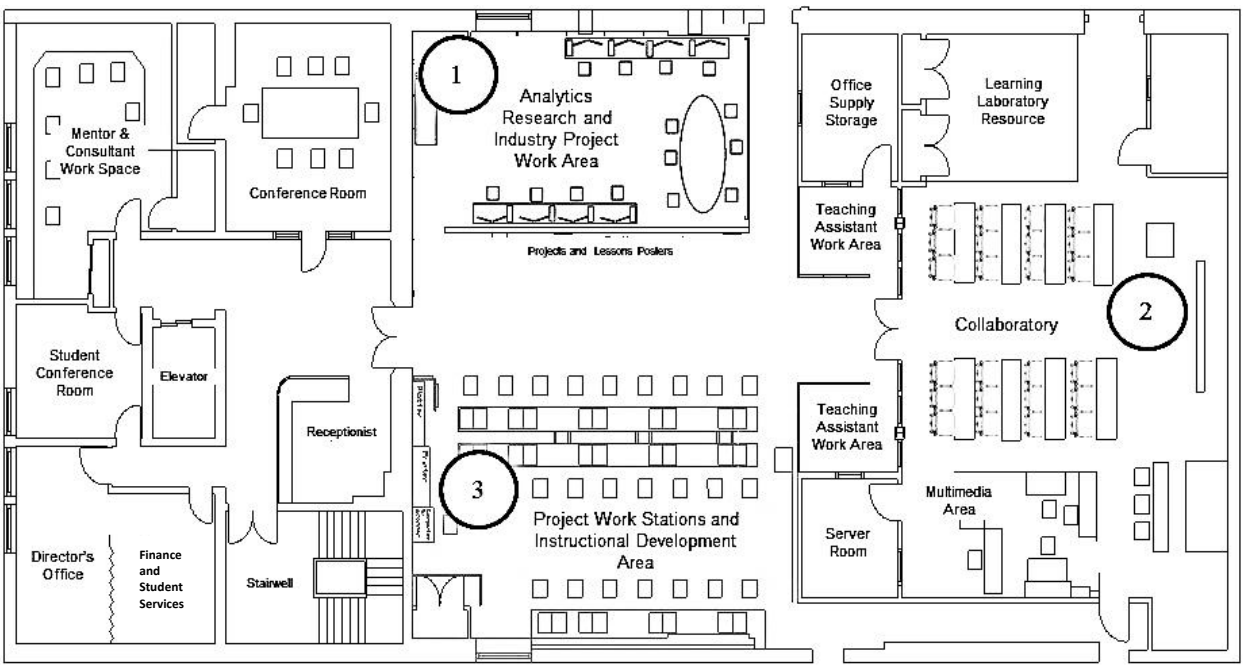

Figure 1: Physical Layout of the Enterprise Systems Center and Advanced Analytics Laboratory

1 **Area one is the Analytics Research and Industry Project Work Area**: In 2013, implementation was initiated for an industry, faculty, and student common work space for research and project teams. Physical construction was completed and this project work area was first used in the summer of 2013 for a variety of analytics projects with private sector businesses and government agencies. In this workspace emphasis is placed on flexibility and ease of project team functioning. Many workstations are not assigned to a specific person. Access to communication resources (on-site and remote) and web-based teleconferencing areas is available. An example of mentor interaction and client teleconferencing in the Analytics Research and Industry Project Work Area is shown in Figure 2 below.

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Figure 2. Example of Mentor Interaction and Client Teleconferencing in the Analytics Research and Industry Project Work Area

2 **Area two is the Collaboratory:** This area is scheduled for the installation of upgraded interactive communication hardware. Its use is for remote conferencing, student project presentations as part of a course (e.g., senior capstone project web-based presentations), and industry interactions with varying group sizes from small to class size. As illustrated in the two photos associated with this area, shown in Figure 3 below, students presenting are located in the front-right of the Collaboratory area. Other students in the room can observe, analyze, and in some cases interact directly with the specific client company. As part of the learning process, students critique presentations given by fellow students. This is done from the perspective of a client company technical or managerial staff member. A written commentary as well as ranking points from 0 to 5 are assigned to the following areas relative to an industry presentation: clear statement of objective, design process, application of tools and techniques, design results and discussion, impact on the business, and overall evaluation of the total presentation.

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Figure 3: Collaboratory Showing Student Presentation with Class Observation and Analysis

3 **Area three is the Project Work Stations and Instructional Development Area**: This laboratory space serves as both a classroom and a pilot area for the development and testing of new course content. Photos of this activity are shown in Figure 4. It is designed to facilitate rapid introduction of new course material and encourages student feedback. Physical renovation was completed and new capabilities were put into service in the summer of 2013. For example, this area is used for the sophomore course which now introduces students to analytics via formal instruction and a case study utilizing Base SAS and SAS Graph software. The workstation layout was designed so that the course instructor and student teaching assistants could easily interact with student teams assigned to a given work station. This coaching function is particularly important when sophomores are challenged with concepts that are often introduced traditionally in upper level courses. Careful sequencing of courses is required to take full advantage of advanced analytics concepts and tools. Therefore, it is believed to be essential that an awareness and understanding of the uses and power of analytics occurs early in a student's career, such as in the sophomore year. This belief was tested in 2013. The feedback received from students and academic advisors was very positive.

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Figure 4: Project Work Stations and Instructional Development Area

Advanced Analytics Laboratory Utilization and Interaction with Industry

As a central part of its implementation and utilization, Advanced Analytics Laboratory personnel have worked to maintain close contact with partner companies to provide students with projects and research opportunities. This section will explain our approach to collaboration with industry partners with the goal of increasing the strategic impact of project work.

The development of the Advanced Analytics Laboratory has allowed an increased focus on the approach to industry interaction, which is referred to as “layered mentoring”. The mentoring structure is multi-pronged, involving consultants as well as faculty members, graduate students, and subject matter experts. Mentors frequently are employed as consultants in the Enterprise Systems Center. These consultants contribute to the Center’s success often after distinguished careers in industry. Their task is to serve as sounding boards and as coaches for student teams which, by design, have a major responsibility for a given project’s successful completion. Without this approach we have found it difficult for student teams to tackle technically challenging company projects, accurately estimate task time duration, and accomplish deliverables that provide measurable value.

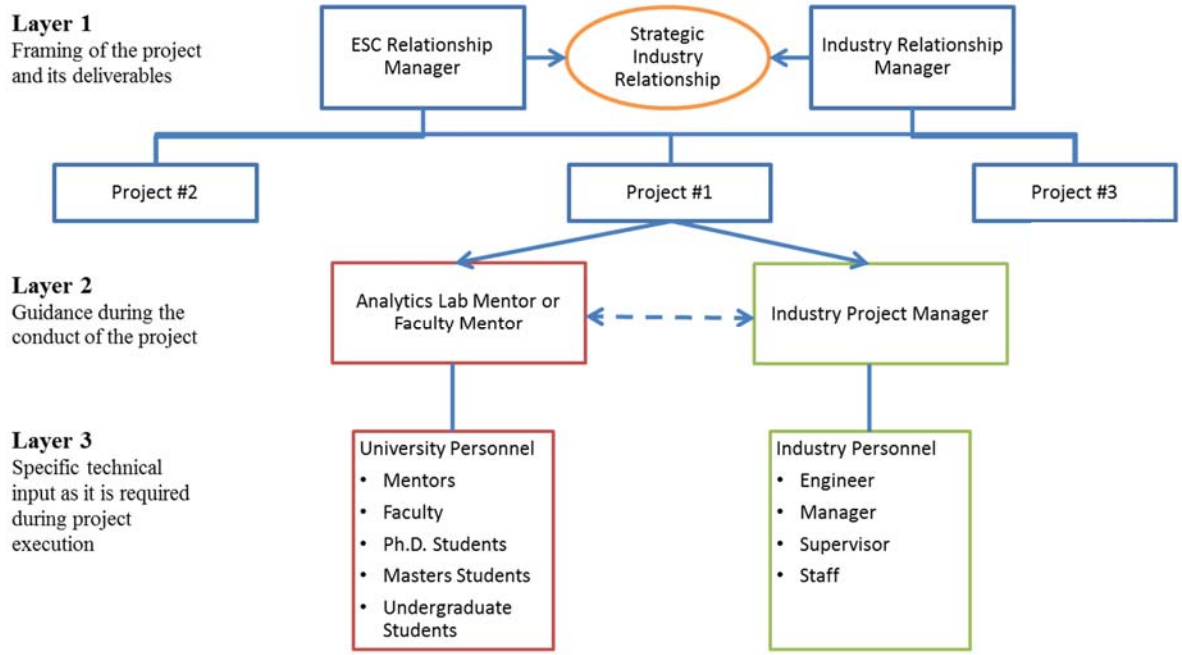

Figure 5: Layered Mentoring Model used by the Advanced Analytics Laboratory

The layered mentoring model utilized by the Advanced Analytics Laboratory is shown diagrammatically in Figure 5. Essentially there are three related layers in this approach. These are described as follows:

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Layer 1: An experienced mentor serves as the client relationship manager and works to develop an understanding of the company's long term objectives. From this understanding with the client, the scope of the work and specific project deliverables are developed.

Layer 2: Advanced Analytics Laboratory and Enterprise Systems Center mentors (usually with consulting and project management experience) and faculty work with students to provide project management guidance. In addition, mentor input is provided with respect to problem solving techniques required to develop solutions and achieve project deliverables.

Layer 3: Specific technical consultation and advice is provided to student teams by mentors, faculty, consultants, and in some cases focused subject matter experts. Peer mentoring is also encouraged whereby graduate students share their advanced knowledge of theory and practice with undergraduate team members.

Students are the core resource around which the project is conceived and executed. The three layers of mentoring provide support in the framing of a significant business problem and its deliverables, guidance during the conduct of the project, and specific technical input as it is required during project execution.

An example project demonstrating the "layered mentoring" approach is the stock keeping unit (SKU) segmentation and production planning parameter guideline determination undertaken with an electronics device manufacturing company. In this case a team of nine was assembled with five students, three mentors, and one faculty, to tackle the project. The problem is based on the fact that while the manufacturing company sells more than 30,000 electronic device SKUs,

about 250 SKUs make up the highest volume and most fluctuation in order patterns. This results in excessive and slow moving inventory of finished goods and raw materials. The current alternative would be to miss orders from the larger-by-volume clients.

For the technical approach (Figure 6) company personnel, mentor(s) with applicable skillsets and students analyzed the project requirements and produced a project milestone path. Initially, forecast data were analyzed using quadrant analysis. The results, together with data analysis of the planning parameters, were used to define a base and performance levels and were then utilized to develop the rules for inventory planning. Next, using company experiential knowledge together with the proposed inventory planning rules, a simulation was developed and the effects of different rules observed and evaluated for usability using 'what-if' and 'sensitivity' analysis. At the project's conclusion the students took the results of their work and planned a presentation to the company Vice President of Operations and other interested parties. "Dry runs" of the presentation were critically reviewed by the mentors who used their experience to guide student presenters to appropriate areas of coverage and presentation techniques to use. This was done so that the recommended replenishment strategies and planning parameters would be understood and adopted.

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For this example, the project team reported that, in consultation with the company, the projected annual inventory savings were $300K to $450K in Finished Goods, and $175K to $325K in Bulk savings. Significant additional benefits to the company included the following: A common language and "rules" for discussion among sales, operations and finance, realistic customer expectations, and reduced cost of servicing low volume SKU's.

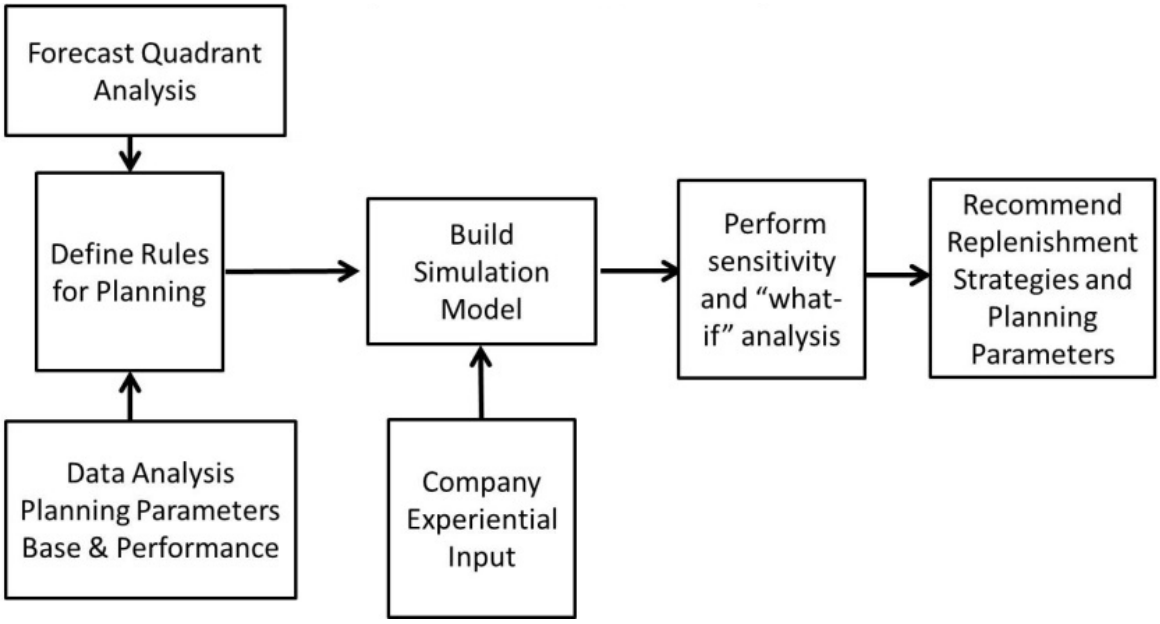

Figure 6: Technical Approach Summary

The following professional background of the mentors working at Layers 1, 2, and 3, is typical in the use of this model to encourage effective industry project structuring and execution.

The Client Relationship Manager, Dan Mulholland, developed the project with the Vice President of Operations at the company (an example of Layer 1 mentoring). Mr. Mulholland is a

consultant at the Enterprise Systems Center and has extensive business experience in sales, marketing, operations, administration, executive management and consulting. For nine years he served as president of Mallinckrodt Baker Inc. (currently Avantor Performance Materials). This background makes him especially effective in helping students understand how to couple core strategies and visions of an enterprise with the analytical tools necessary for successful business operation.

Project Management mentoring support was handled by Sekar Sundararajan (an example of Layer 2 mentoring). During his career Mr. Sundararajan contributed to the implementation of agile manufacturing practices and the application of analytics to the development of global supply chains in several organizations such as Ford, General Motors, and Kraft Foods. His M.S. degree in ISE with Operations Research specialization as well as his corporate experience make him well suited to mentor our students in the conceptualization of high level organizational mission, understanding of global perspectives, as well as managing projects using tactical tools such as those typically associated with analytics.

In this project there were two technical advisors (an example of Level 3 layered mentoring). Dr. Bob Storer is a Professor of ISE. His research interests include heuristic optimization, logistics, scheduling and routing, combinatorial optimization, and “balancing and partitioning”. Dr. Storer teaches courses in heuristic optimization, simulation, and applied statistics. He joined the ISE faculty in 1986.

Tom Brinker, has worked with ESC for the past three years and was previously in charge of the Decision Sciences group at Air Products, Inc. During his time of leadership the prestigious INFORMS Prize was awarded to Mr. Brinker’s group for effective integration of operations research/management sciences (OR/MS) in an organization. He is an active member of the Institute of Industrial Engineers (IIE), the Council of Logistics Management (CLM), and the Production and Operations Management Society (POMS). Mr. Brinker’s industry experience equips him to comfortably fulfill the requirements in the Level 1, 2, or 3 mentoring structure.

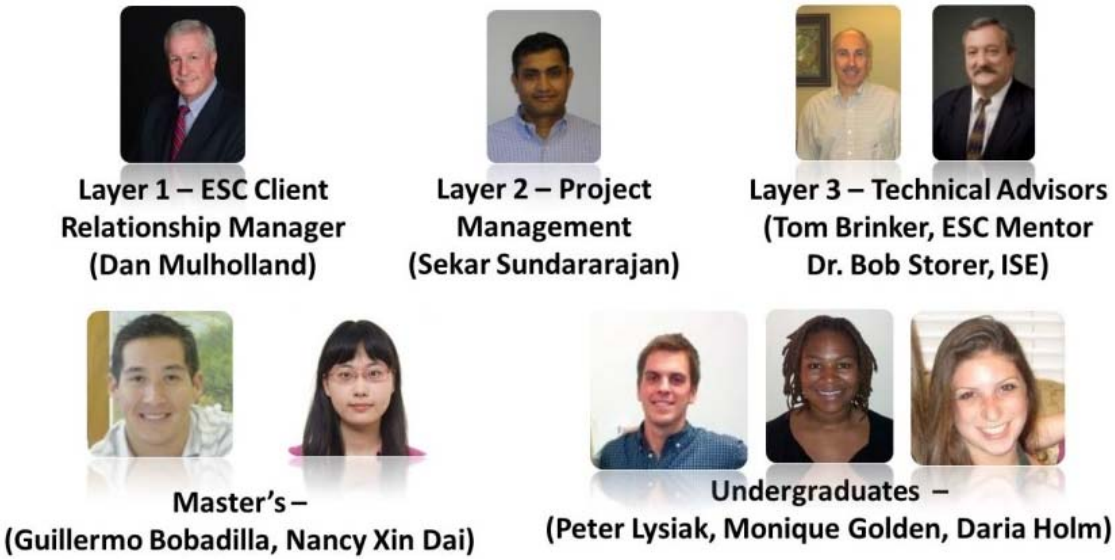

Figure 7: Project Team Structure (Layered Mentoring)

This layered mentoring approach between the ESC and its industry partners also benefits the faculty of the ISE Department by helping identify the most pressing and pervasive application of analytics that interest industry partners. Awareness of key issues on the mind of various companies assists in identifying new course content and helps to make the Department's graduates more marketable and better prepared to face the challenges of the real world.

Using the Advanced Analytics Laboratory, projects can be of variable duration, and teams can be sized according to project scope. Specifically, students can work on:

- Senior capstone course projects: 2 to 4 students per team, 6 hours per week per student. The course is ISE 254, Senior Project, which covers the use of industrial and systems engineering techniques to solve a major problem in either a manufacturing or service environment.
- Summer projects or fall (co-op) projects: 480 hours per student.
- Graduate student projects: 10 to 20 hours per week per student per semester
- Leadership minor: leadership projects are semester long projects, 6-8 hours per week. The course is ISE 281, Leadership Project, and it covers the application of leadership principles through team projects with industry.
- Course projects: 1 to 2 students per team, short, customized projects were time allocation varies depending on the project requirements. The course is ISE 321, Independent Study in Industrial and Systems Engineering, and it covers experimental projects in selected fields of industrial engineering, such as analytics.

Support of Coursework and Related Educational Objectives

The Advanced Analytics Laboratory is being utilized to support educational objectives building on a collaborative structure linked to a long-standing partnership with the Department of Industrial and System Engineering (ISE). Analytics has been identified by the ISE Department and its industry advisory groups as a very high educational priority.

The first course example is for ISE 112 (Computer Graphics). An analytics pilot program was introduced in 2013 which permitted students to select a design graphics or a new presentation graphics track. For the presentation graphics track, a case study was created based on an Advanced Analytics Laboratory project with industry. This case was developed by Dr. Charalambos Marangos, serving in the dual role of adjunct professor and consultant in the Advanced Analytics Laboratory. Base SAS and the reporting solution Graph-N-Go, was used to generate the graphics case deliverable. This new presentation graphics content was well received by the students during the course transition. In 2014 the case was expanded and instructional content was documented.

The next course example of Advanced Analytics Laboratory use to support course work is for ISE 230 (Introduction to Stochastic Models in Operations Research) and ISE 240 (Introduction to Deterministic Optimization Models in Operations Research). Starting in the Spring of 2012, the Industrial and Systems Engineering (ISE) Department at Lehigh University introduced these two new courses to satisfy the need for quantitative techniques from both optimization and stochastic processes. This allows students in the ISE curriculum to appropriately support current decision-making problems in practice. Both courses focus on the introductory concepts and techniques in operations research and stochastic processes. The main job of developing these new courses was assigned to Dr. Luis Zuluaga, Assistant Professor of ISE. As reported by Professor Zuluaga, during the process of designing the new courses, it became evident that the students enrolled in them needed to be highly knowledgeable in the use of state-of-the-art

software in probability, statistics, and optimization. Consequently, one of the software tool suites chosen for the course is from SAS. The decision was based on appropriate software availability for both stochastic modeling and optimization.

In ISE 230 (Introduction to Stochastic Models in Operations Research), offered in the Spring 2013, the students had the opportunity to use SAS software to analyze how stochastic chains that might not satisfy all the theoretical conditions for the chain to be Markovian, can still converge to a steady state. To observe this, SAS simulation tools were successfully implemented and used by the students. In ISE 240 (Introduction to Deterministic Optimization Models in Operations), students have the opportunity to solve large-scale, real-world optimization problems using the SAS optimization capabilities. Course Instructor, Dr. Zuluaga states, "In the future, I expect this trend of using SAS as an integral part of the two courses mentioned above, will only continue to increase. In the future, I would be seeking for these two courses to always have access to facilities such as the Advanced Analytics Laboratory where the students will have first-hand access to appropriate computer and software resources when needed for class assignments."

The final course example in which the Advanced Analytics Laboratory is used to support course work is the Capstone Course for Industrial and Systems Engineering (ISE 254). This course frequently leverages both the physical resources and the company relationships maintained by the Advanced Analytics Laboratory. As a result of the capstone experience, senior ISE students are able to develop an approach for solving unstructured problems in a real-world setting, and learn how to select and apply specific design and analysis tools to the problem, as well as justify and document the tools that were employed. In addition, seniors are able to design a new or improved system as appropriate to their project. Project teams are required to develop and present a comprehensive final report articulating the design process that was followed as well as the final design itself. When appropriate, seniors conduct project meetings or present results using collaborative technologies such as interactive conferencing available to them in the Advanced Analytics Laboratory.

The following examples of industry projects are intended to provide the reader with a general overview of the types of work undertaken and typical project deliverables. A number of active analytics projects have been developed from 2013 through 2015. These projects intensively utilize the Advanced Analytics Laboratory. The types of organizations and analytics projects include:

- **Type of Organization:** Transportation Services
  Business Unit: Infrastructure Maintenance and Repair
  Software: SAS Enterprise Guide, SAS Enterprise Miner
  Deliverable(s): Apply data mining to all maintenance activity. Emphasis on timing, prediction, and determining the most cost-effective procedures.
  Project Continuation Deliverables: Improved strategy and operational guidelines including predictive features
- **Type of Organization:** Chemical Company
  Business Unit: Liquefied Natural Gas
  Software: Arena, Excel Structuring, SAS Enterprise Guide, SAS Enterprise Miner
  Deliverable(s): A study of competitive market, economic, financial, supply chain, and technology analysis.
- **Type of Organization:** Electric Utility Company
  Business Unit: Network Distribution, Storm Response and Recovery

Software: SAS Enterprise Guide, SAS Enterprise Miner
Deliverable(s): Analysis, design recommendations, and simulation

- **Type of Organization:** Electronic Device Manufacturer
  Business Unit: Inventory Management
  Software: SAS Enterprise Guide, SAS Enterprise Miner
  Deliverable(s): SKU segmentation analysis, inventory level, and demand prediction modeling
- **Type of Organization:** Fortune 500 Pharmaceutical Company
  Business Unit: Marketing
  Software: SAS Enterprise Guide, SAS Enterprise Miner
  Deliverable(s): Salesforce effectiveness, optimal use of marketing resources, identify metrics for analytics effectiveness linked to growth of sales.
- **Type of Organization:** Global Consulting Company
  Business Unit: Forensic, Healthcare Analytics
  Software: SAS Enterprise Guide, SAS Enterprise Miner, SAS Text Miner
  Deliverable(s): To be determined, could include new client offerings
- **Type of Organization:** Hospital Network
  Business Unit: IT Department
  Software: SAS Enterprise Guide, SAS Enterprise Miner
  Deliverable(s): Identify improvement opportunities using newly available operational data.
- **Type of Organization:** Hydraulic Equipment Manufacturer
  Business Unit: Sales and Marketing
  Software: SAS Enterprise Guide, SAS Enterprise Miner
  Deliverable(s): Sales cross-selling analytics and new marketing strategy
- **Type of Organization:** Medical Equipment Manufacturer
  Business Unit: Procurement
  Software: SAS Enterprise Guide
  Deliverable(s): Data visualization, investigate analytics findings. Demonstrate use of analytics for predictive raw material pricing.
- **Type of Organization:** Equipment Manufacturer
  Business Unit: Plant maintenance area
  Software: SAS Enterprise Guide, SAS Enterprise Miner
  Deliverable(s): Predictive maintenance procedures and technology-driven strategic guidance.
- **Type of Organization:** Regional Energy Supplier
  Business Unit: Call Center Operations
  Software: SAS Enterprise Guide, SAS Enterprise Miner
  Deliverable(s): Forecast call volume and analysis of current operational procedures. Support in the development of efficiency and response metrics.
- **Type of Organization:** Equipment Manufacturer
  Business Unit: Sales and Marketing
  Software: SAS Enterprise Guide, SAS Enterprise Miner
  Deliverable(s): Cross-selling opportunity identification. Development of new business strategies.

- **Type of Organization:** Transportation Company (Rail)
  Business Unit: Track Maintenance
  Software: SAS Enterprise Guide, SAS Enterprise Miner
  Deliverable(s): Demonstrate the value of analytics in improving traditional decision processes for track maintenance.
  Project Continuation Deliverables: Follow-up investigation. Expansion of analysis to increased data capacity and track mileage. Evaluate use of analytics for predictive maintenance procedures at the increased size.
  Additional Project Continuation Deliverables: Building on previous project experience, model and implement analytics for predictive raw material pricing.

The authors' experience indicates that it is relatively straightforward to undertake industry projects that utilize traditional industrial engineering techniques. It is the Advanced Analytics Laboratory's objective to challenge the student with projects utilizing analytics or similar tools and techniques. It is the belief of the authors that in order to accomplish their educational objectives the following must be in place: the previously discussed infrastructure of the Advanced Analytics Laboratory, strong industry relationships built on trust and a history of performance, collaboration with the ISE Department, and a strong mentoring structure.

Evaluation of Student Outcomes and Continuous Improvement of Advanced Analytics Laboratory Operations

Because of the short time period of Laboratory operation, the discussion on student outcomes and continuous improvement will be limited to the approach that is currently being implemented and utilized. Reporting of well-documented student outcome results is premature. However, early anecdotal feedback such as student and industry partner testimonials has been very positive.

Evaluation of student outcomes methods were proposed by our industry partners, faculty, students, mentors, and companies that historically hire our students. This diverse group of stakeholders share many common objectives. However, there was not a clear-cut consensus concerning the evaluation of student outcomes.

Ultimately, it was decided to utilize selected components of internal documentation providing guidance in the mapping of student outcomes to performance indicators as part of the ISE Department accreditation process. Factors leading to this decision included the following:

- Metrics associated with the accreditation process were well-tested and accepted.
- Developing a new approach would likely drain resources from critical operational needs of the Advanced Analytics Laboratory.
- There was general acceptance among stakeholders of the structure and content of the accreditation-related approach.
- Potential efficiencies in cross-utilization of work products for other university reporting and analytics programs.

An initial listing of outcomes determined to be appropriate for the Advanced Analytics Laboratory's educational mission are outlined as follows:

Student Outcomes Associated with the Advanced Analytics Laboratory Educational Objectives *(adapted from ABET Criteria for Accrediting Engineering Programs)*

A. An ability to identify, formulate, and solve engineering problems

1. Integrate subject areas in industrial and systems engineering, science, mathematics, physics, and other engineering disciplines into the solution of engineering problems.
2. Develop appropriate strategies for identifying and solving engineering problems, including applications of engineering science for practical situations.
3. Locate and use appropriate resources to solve problems.
4. Make appropriate assumptions to enable reaching a practical solution and assessing the validity of the solution and how it is impacted by the assumptions.
5. Use advanced technology appropriately to solve complex industrial and systems engineering problems.

B. An ability to function on multidisciplinary teams

1. Generate a comprehensive report of the team project work with clear assigned tasks (application).
2. Demonstrate comprehensive understanding of a multidisciplinary team project work in a presentation (application).
3. Employ project scheduling tools with delineation of tasks, assignments, deadlines that demonstrates the collaborative activity (application).
4. Provide peer evaluation and peer feedback throughout duration of team project.

C. An ability to communicate effectively

1. Understand the purpose of different forms of technical communication (written and oral; e.g., abstracts, reports, papers, letters, posters, and presentations) and under which circumstances each form is most appropriate (knowledge).
2. Prepare clear and concise written documents (abstracts, reports, papers, letters, posters) (application).
3. Deliver effective oral presentations to engineers and general audience (application)
4. Use high quality, peer reviewed references and include proper citations in written and oral work (application).
5. Use visual aids (images, diagrams, photographs, three dimensional presentation graphics) to enhance communication efforts (application).

D. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context [Briedis 2002]

1. Describe and discuss current trends in the industrial and systems engineering discipline including operations research, management science and analytics.

2. Read and be able to relate the content of periodicals and online scholarly references that are relevant to understanding the global and societal impact of engineering.
3. Analyze historically important engineering system failures and their impact on society and engineering solutions for the future.
4. Combine knowledge of potential impacts into system design and problem-solving process.

E. A recognition of the need for, and an ability to engage in life-long learning [Briedis 2002]

1. Be proficient in the use of a variety of informational and educational media such as traditional textbooks, scientific and technical journals, the library system as a whole, and internet resources, software design specifications and standards.
2. Have an understanding of and exposure to the breadth and structure of the professional and technical support system that will be available upon graduation; this includes professional and technical societies, the continuing education needed to maintain professional relevance, and professional registration systems such as that provided by the INFORMS Analytics Certification Candidate Handbook.
3. Have an awareness of the dynamic, evolving nature of science, engineering, technology, and industry, and an understanding that learning does not end with the B.S. degree.
4. Have the ability to learn on their own by following examples.
5. Demonstrate curiosity and innovation by proposing topics of independent study or engaging in independent study/research.
6. Provide peer-to-peer critical feedback to enhance the clarity and overall quality of written documents and oral presentations (analysis).

F. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

1. Choose appropriate modeling and analysis approaches compatible with the defined systems requirements (knowledge).
2. Demonstrate proficiency in the use of modern computational tools and specific software for professional practice in the area of analytics, operations research management science (application and analysis).
3. By means of simplified approaches, interpret and verify the results obtained by advanced analysis tools (synthesis and evaluation).

As the Laboratory continues to evolve, it is planned that stakeholders, the industry advisory group helping to guide development, and the faculty committee that provides input on educational metrics, will offer constructive suggestions. At this state in the Laboratory implementation, the important task of working to accurately measure and analyze student outcomes is underway. As time passes, trends should emerge and confidence in our measurement techniques will likely improve. It is our expectation that an increase in the number of students utilizing new resources will energize continuous improvement efforts.

It is the authors' observation that many educators and industry sponsors believe that a systematic commitment to continuous improvement is an essential element in the operation of engineering laboratories. A commonly utilized improvement cycle has the following components: The first is the development of an annual plan that builds on the basic Laboratory mission statement. The second is Plan Execution which involves completion of required tasks such as data collection associated with the student outcomes assessment process. The third component is the analysis of data, consolidation and formalizing of lessons learned. The fourth and final component of the continuous improvement cycle is the structuring of improvements to be made. This includes stakeholder feedback and, where appropriate, commitment to support the next cycle of planning and Laboratory operation. This approach to continuous improvement has been adopted and is being implemented.

Future Initiatives

Future initiatives relative to the Advanced Analytics Laboratory will include the development of an "Analytics Minor". The establishment of this specific minor will help to guide students with respect to course work and special projects. It will also increase the visibility of career opportunities to students when they are in their freshman and sophomore years. Work in this area will be done in close coordination with the Industrial and Systems Engineering Department and interested faculty across Lehigh University.

The second future work area is the development of case studies and related educational materials that will support "leadership enhanced through analytics." The Enterprise Systems Center is currently the home for a portfolio of leadership development programs at the University (Leadership Minor, the Lehigh Chapter of National Society of Leadership and Success, Innovation and Leadership Residency Program, Alumni Leadership Insights Program, and several courses in leadership development). Efforts are underway to conceptualize and formalize educational content showing the strong linkages between successful leadership and the understanding and utilization of analytics techniques. A central theme is the following: For the leaders of tomorrow's technology- and data-driven businesses, competency with analytics concepts and software tools is an important enabler. Graduates who have undertaken programs involving leadership development and have strong skill sets in analytics, often as a direct result of their work with industry via the Advanced Analytics Laboratory, will be in heavy demand. They will be employed as individual contributors, managers, and potentially executives, in a variety of private and public sector enterprises.

A third and final area is the establishment of a university-wide "Collaborative Analytics Forum." This will involve selected members of both teaching and research faculty working in fields directly or tangentially related to analytics. They will be invited to be part of the Collaborative Analytics Forum which will bring together the Advanced Analytics Laboratory, industry partners, Lehigh University personnel and students to accelerate learning opportunities, promote best practice sharing and explore new opportunities. The objective is to help identify and bring the most recent research developments into the classroom and also support their utilization in industry project work. In addition, research needs are frequently identified during the conduct of industry projects. As a part of the Forum activity, appropriate communication channels are identified and maintained.

Summary

The objective of this paper has been to provide an overview of the design, implementation and utilization of the Advanced Analytics Laboratory in support of educational programs and industry partnerships within the Enterprise Systems Center (ESC) at Lehigh University. To assist in this process the evolution of the ESC is described along with the physical layout of the new Laboratory. Three laboratory areas encourage team interaction, ease of communication with off-site industry partners, and promote piloting of new educational content. Key team members (students, mentors, faculty, and industry partners) all contributed to the Laboratory design effort.

An important part of the Advanced Analytics Laboratory mission is to enhance the educational process by utilizing experience-based learning facilitated by mentoring resources. The mentoring program adds to typically available university skill sets. The use of the Laboratory for course content development is described for several courses. The industry relationships developed and maintained by the Laboratory are leveraged for student course project work adding to the realism and level of technical challenge. This is especially useful for the Industrial and Systems Engineering Department's Capstone course as well as other project organizational structures.

In a latter section of the paper a discussion is provided outlining the specific information tracked with regard to student outcomes. One of the purposes of using this process is to establish a closed loop methodology driving continuous improvement in laboratory operations and associated educational efforts.

In the last section future initiatives are outlined. This information is intended to share with the reader Laboratory linkages with respect to an Analytics Minor, associated leadership development programs and a university-wide Collaborative Analytics Forum hosted by the Advanced Analytics Laboratory.

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Biographical Information

Prof. Emory Zimmers is a Professor of Industrial and Systems Engineering at Lehigh University and Director of the Enterprise Systems Center and the Advanced Analytics Laboratory. In this capacity he works extensively with companies to identify critical new areas for research and provide experiential learning opportunities for students through industry projects. He has co-authored a book with Dr. Mikell Groover titled, "CAD/CAM: Computer Aided Design and Manufacturing" and served as Site Director of the National Science Foundation's Center for Engineering Logistics and Distribution (CELDi) at Lehigh University (2005-2010). He has served as principal investigator on more than 800 research and technology transfer projects with over 400 industry partners. Dr. Zimmers is both a Fellow of the Institute of Industrial Engineers and the Society of Manufacturing Engineers. He is member of the American Society for Engineering Education.

Prof. Zimmers supervises the senior capstone course, which is a requirement for students graduating with a BS in Industrial and Systems Engineering. He headed the team that created the leadership development course, which was a finalist in the Institute of Industrial Engineers' Innovations in the Curriculum award competition in 2009. Dr. Zimmers was awarded the 2011 Lindback Award for Distinguished Teaching.

Dr. Zimmers has consulted for numerous companies and government agencies including IBM, General Electric, Boeing, Department of Defense, and Pennsylvania Department of Community and Economic Development. He received the Robinson Award from Lehigh University for outstanding service to the university community.

Charalambos A. Marangos, PhD: Consultant for the Enterprise Systems Center's Advanced Analytics Laboratory and President and Founder of Zephyros, Inc., a consulting firm that specializes in solving the problems of business and industry. Dr. Marangos has served as a developer and instructor for part of an innovative sophomore-level engineering graphics course that introduced students to SAS. This allowed him to create new course content and simultaneously evaluate pilot course material in real-time basis. Dr. Marangos recently has served as the Associate Director of the NSF-funded Center for Engineering Logistics and Distribution (CELDi) at Lehigh. He has written many papers and is a co-author of the Computer-Aided Design chapter in the upcoming 4th edition of the Mechanical Engineer's Handbook. A Fulbright Scholar, Dr. Marangos earned his doctorate degree from Lehigh University in Industrial Engineering with a specialization in operations research. He is a member of the Institute of Industrial Engineers.