What Distinguishes the ISE Undergraduates Curriculum

Industrial and Systems Engineering (ISE) seems to struggle with the challenge of explaining to the lay person exactly what it is that ISE professionals do. The underlying assumption is that other engineering disciplines are adequately defined by their name—EEs light homes and make cell phones, AEs make airplanes and rockets, MEs make cars, and so on. In fact, the challenge is much more difficult today than it was in 1948 when AIIE was formed. So recently, I decided to try to ascertain what we, as a community, think it is that distinguished ISE from other engineering disciplines. I asked a broad section of the profession to respond to the following:

> "Please identify three or more key industrial and systems engineering principles, methods, or tools that you think ***every*** industrial and systems engineering undergraduate should be exposed to and/or master prior to graduation because they clearly distinguish the graduate as an *industrial and systems* engineer. A brief (2-3 sentence) rationale for each choice would be helpful but not absolutely essential."

The respondents—many of whom are Fellows of the Institute--included active and retired faculty, practicing IEs, and consultants. Some responses were very brief and some were quite detailed. All responses provided interesting information and insights.

One respondent provided the ABET criteria for accreditation, which I probably should have referenced in the original request. Those criteria allow for a pretty wide range of curricula to be approvable, so a fundamental question confronting every undergraduate ISE program is "How shall WE meet the criteria?" In answering that question, perhaps these survey results will be useful.

In an attempt to make these responses actionable, I have extracted three kinds of information. First, I've summarized (and anonymized) the responses, as shown in Appendix A. It was clear from Appendix A that the responses fall into categories, so I attempted to identify those categories and summarize the content of each category. Those results are detailed in Appendix B. Finally, I attempted to understand what it all means. My conclusions are contained in the following section. If, in these efforts, I've misunderstood or misconstrued some input, then I apologize and will make a sincere effort at correction. If you find the information or the conclusions either interesting or disturbing, please contact me to let me know (leon.mcginnis@gatech.edu).

What It All Means, Maybe

The items listed under "What students should know/learn" represent quite the spectrum of ISE curriculum content, from pre-Roy Report content like work methods and measurement, to post-Roy Report rigor like optimization and stochastics, to content never anticipated in the Roy Report, like data science and evolutionary optimization. This presents a fundamental challenge in trying to identify anything that looks like a "core curriculum" for ISE undergraduates. Here's why.

Since the mid-sixties, when the Roy committee was doing its work, the content of all undergraduate engineering curricula has shrunk dramatically because:

- the vast majority of programs have transitioned from quarters to semesters, meaning fewer total course offerings,
- the number of credit hours for an undergraduate engineering degree has shrunk dramatically, and
- the number of required non-engineering courses has grown.
- ISE students today often are encouraged to take courses from other disciplines, such as biomedicine, bioengineering, computer science or others. This provides them with great opportunities to pursue their interests while at the same time reducing their exposure to the distinguishing coursework for ISE.

The bottom line is that we have fewer and fewer credit hours to inculcate ISE principles, so it is more and more important for us to understand what that means.

In a similar way, the items under “What students should be able to do” represent quite a spectrum of capabilities, and I suspect most ISE professionals would agree that these items do represent ISE capabilities. Today, in large part, we depend on our capstone design experience to develop these kinds of skills. It might be an interesting experiment to see how many of them currently have any representation in our curricula.

I am forced to confess that I’ve never really attempted to identify what I think constitutes essential ISE “wisdom” but this exercise has convinced me that it’s a topic deserving much more attention.

Finally, I did some text analysis of the raw responses, and the word appearing most often was systems. Appendix C lists all the ways in which “systems” appeared. It strikes me that in ISE, we talk about systems a lot, but always in somewhat vague and ambiguous ways. We use the word in describing the domains of practice, like logistics systems, production systems or inventory systems, but we have no more formal definitions of those kinds of systems. We also talk about issues like architecture, design, analysis, etc, but for the most part, ISE curricula do not treat systems in any formal way, although we do show how to apply our basic OR methodologies in certain system domains.

Conclusion

Our world is changing. The ability of our students to find and use information and, yes, tools, is growing rapidly due to generative AI. If we don’t know how to distinguish ISE as a professional discipline, then why do we need to continue to exist as one? We need a clearer, less ambiguous and compelling answer to the question “What distinguishes ISE from other disciplines?”

Appendix A: Summary statements from the Responses

In order to rationalize these quite varied responses, I have attempted to summarize them in statements that could be viewed as "advice" to a matriculating ISE undergraduate. There are more than 37 items, because many of the responses included significantly different ideas. The items are in alphabetical order, since I could not think of a better organization.

- [Be able to focus on] continuous improvement, optimization, process variation, data-driven decision making, people, systems, and economics.
- [Be capable of] Calculating confidence intervals/performing hypothesis testing, [solving] a linear program using the simplex method, evaluate and improve the performance of a system
- [Be capable of] systems thinking, basic program management, and basic decision science.
- [Be capable of] Understanding/developing the operations model of the enterprise and having a solid/diverse set of tools/techniques that can be implemented to positively impact enterprise performance.
- [Be prepared for] technological innovations (LLMs to virtual reality), skill based employment and gig economy, global reach of instruction (EdX, Coursera, etc).
- [Get an introduction] to system engineering/project management, optimization, human-systems interaction, and logistics systems.
- [Have a] deep and solid understanding of engineering economy and the economic/financial drivers of enterprise performance, including a basic understanding of markets.
- [Have a] strong understanding of system modeling and optimization tools and skills
- [Have an understanding of] engineering economics, statistics and probability, and operations research.
- [Have an understanding of] engineering economics; analytics; system modeling and analysis
- [Have an understanding of] formulating and solving optimization models, sequencing/scheduling and facility location problems, and data science methods.
- [Have an understanding of] human factors and ergonomics, lean operation and six sigma, and operations research.
- [Have an understanding of] methods, work measurement and ergonomics; engineering economics; presenting and selling, especially to those who are negative to the results.
- [Have an understanding of] modeling and optimization; process flow/improvement; supply chain and inventory optimization; statistical analysis and DOE; and human factors.
- [Have an understanding of] optimization…probability and statistics…and queuing theory.
- [Have an understanding of] systems thinking, supply chain management, and foundational methodologies (statistics, simulation, optimization, etc).
- [Have an understanding of] Types of Manufacturing Systems, Group Technology, Assembly Line Balancing, Lean Engineering, Scheduling approaches in discrete manufacturing, and Process Planning & Manufacturing Systems.
- [Have capability for] work methods and measurement, process control and capability, statistically designed experiments.
- [Have capability in] trade-offs between conflicting objectives; optimization; engineering economics; probability and statistics; and Markov chains.
- [Have capability in] understanding [human] work, ergonomics and human factors, DIKW pyramid.

- [Have capability to] build and validate a discrete event simulation model; conduct a multi-factor experiment; [use] a systems analysis methodology/approach; [do a] Risk Assessment that embodies qualitative and quantitative methods; [understand] Data: how to extract it, how to manipulate it, how to explore it, how to interpret it, and how to decide what models to use; [use] agile principles and how to be successful and lead in this work environment.
- [Have understanding of] data science, design of digital systems, evolutionary optimization, and innovation.
- [Know how to] Engineer Management Systems, including; value stream mapping; visible measurement systems; strategic performance improvement planning and deployment; change leadership and management; integrated lean and six sigma.
- [Learn] how best to engage the human resources of an enterprise to drive improved performance over time.
- [Take courses in] computer science, simulation, human factors engineering, principles of manufacturing systems, statistics and probability, operations research, and engineering economy.
- [Understand that] reducing setup/changeover cost is key to improving performance
- [Understand] Little's Law
- Be able to identify all who make input to a system and all who use its output, understand how those inputs affect other users of the system and their behavior, [design systems to] prevent the input of erroneous data whether accidentally or intentionally.
- Create a precise model of a system. … "precise" means that it should be clear enough that if 5 competent industrial engineers read the model, they should all be able to understand and reproduce it
- Don't just implement a model then worry about determining parameters afterwards. Also, think hard about how uncertain you are about those input parameters and how that uncertainty may play out with your selected decision.
- Great technical innovation won't be accepted if it changes the way of working of people and they don't understand and embrace the change.
- Quantify uncertainty and the consequences of uncertainty and propose reasonable hedges against uncertainty.
- Small is Good/Simplicity is Good
- Specify rational methods of decision making for any decision situation … This may involve optimization, but it is not the same – many optimization problems formulated by industrial engineering students have irrational objectives.
- There is no such thing as a single model that answers all questions.
- understand probability, statistics and stochastic modeling
- When tackling any problem, start with the simplest model you can think of, take it all the way through to the conclusion, then improve the model as time permits.

Appendix B: Categorizing the Responses

After reading the responses several times and thinking about them, I attempted to extract categories of responses and summarize the key terms within each category. This is, again, my own interpretation, and if it is incorrect, I apologize.

What students should know/learn:

- assembly line balancing
- data science
- decision science
- DIKW pyramid
- DOE
- Engineering economy
- evolutionary optimization
- facility location
- group technology
- human factors and ergonomics
- human-systems interaction
- Lean and 6 sigma
- Little's Law
- optimization
- probability and statistics
- process control
- program management
- project management
- sequencing and scheduling
- simulation
- stochastic, queuing theory
- value stream mapping
- work methods and measurement

What students should be able to do:

- apply agile principles
- change leadership and management
- continuous improvement
- create system models
- data-driven decision-making
- develop enterprise level operations models
- engage human resources
- identify all system stakeholders
- positively impact enterprise performance
- present and sell recommendations
- process flow improvement
- propose hedges against uncertainty
- quantify uncertainty and its consequences
- service-centered leadership
- trade-off conflicting objectives

Fundamental ISE "Wisdom"

- consider data availability and quality when formulating models
- innovation success requires understanding and acceptance
- prepare for technology innovation
- reducing setup/changeover cost is process improvement key
- small/simple is good
- start simple and elaborate as needed
- there is no single model that answers all questions

Appendix C: About "Systems"

The word "systems" appeared over 65 times in the 37 responses. Here are the ways in which the word appeared:

- digital systems
- human-systems interaction
- operating system
- software system
- system analysis methodology
- system architecture
- system design
- system focus
- system interface
- system model
- system reliability
- system stakeholders
- systems engineering
- systems thinking