Developing Competence in the Systems Engineering Professional Competencies

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Abstract. In 2018, the International Council on Systems Engineering (INCOSE) introduced a set of competencies for systems engineers in a framework structure that gives guidance as to the knowledge, skills, abilities, and behaviors important to systems engineering effectiveness at each of five "levels" of competence. These levels range from awareness to expert. There are five categories of competencies: Core, Technical, Professional, Systems Engineering Management, and Integrating.

The purpose of this paper is to provide research-grounded methods for improving one's competence in the INCOSE Professional Competencies, while recognizing that improvement strategies may not be universally applicable due to gender- and culturally-based differences in strengths and weaknesses relative to the Professional Competencies. Specifically, the paper addresses ways that systems engineers can improve their own competence in these key areas.

Introduction

Holt and Perry (2011) define competency as "a measure of an individual's ability in terms of their knowledge, skills, and behavior to perform a given role (pg. xvi)." Competency is distinct from competence, which is the ability to do something well (Merriam Webster n. d.). Competence reflects the total ability of the individual, while a competency reflects a single skill; the sum of an individual's competencies makes up their competence (Holt and Perry).

Competency frameworks describe the set of competencies that apply to a particular field or role. Organizations and individuals have numerous use cases for competency assessment. Organizational uses include recruiting and selecting employment candidates; making appraisal, promotion, and compensation decisions; providing developmental opportunities; aligning organizational structures to maximize organizational capability; and identifying workforce training requirements (Holt and Perry 2011; Skills for the Information Age 2011).

The INCOSE Competency Framework

In 2018, the International Council on Systems Engineering (INCOSE) introduced the *Systems Engineering Competency Framework*[1] (hereafter called the Framework) which provides a set of Systems Engineering (SysE) competencies in a framework structure that gives guidance as to the knowledge, skills, abilities, and behaviors important to SysE effectiveness in the domain in which the competency model is applied. The framework can be applied in any context and can be (in-

[1] All references to the INCOSE Competency Framework are from Presland, ed., 2018 unless otherwise cited.

deed, is expected to be) tailored to suit the application domain and/or integrated with other complementary frameworks.

There are five "levels" of competence outlined, ranging from awareness to expert, in each of five categories of competencies:

- Core Competencies that underpin both engineering and SysE. Capability engineering, which refers to the delivery of a desired outcome rather that the delivery of a desired performance level, is one of the SysE Core Competencies. Others are Systems Thinking, Lifecycles, General Engineering, Critical Thinking, and Systems Modeling and Analysis
- Technical Competencies that are associated with the technical processes identified in the *INCOSE Systems Engineering Handbook* (Walden et al., eds. 2015; hereafter called the Handbook) – Requirements Definition, Systems Architecting, Design for…, Integration, Interfaces, Verification, Validation, Transition, Operation and Support
- Professional Competencies that reflect behaviors established within the human resources domain. A detailed listing of these competencies is given in the next section
- SysE Management Competencies that relate to managing and controlling SysE activities. These include Planning, Monitoring and Control, Decision Management, Concurrent Engineering, Business and Enterprise Integration, Acquisition and Supply, Information Management, Configuration Management, and Risk and Opportunity Management
- Integrating Competencies that recognize that the SysE discipline joins its activities with those of other disciplines, including Project Management, Finance, Logistics, and Quality, to create project coherence

Beasley et al. (2019, pg. 301) hailed the inclusion of the Professional Competencies in the framework as a "significant development".

Rationale for Focusing on the Professional Competencies

The Framework contains an annex that analyzes the alignment of the framework with other INCOSE initiatives. In looking at the alignment with the Handbook (Walden et al., eds. 2015), one sees that there is virtually no alignment between the Handbook and the Professional Competencies (this is being addressed in the 5th Edition [under development], which does address the Professional Competencies). There is some overlap between the Professional Competency of Negotiation and the Technical Competencies of Requirements Definition and Verification and Validation, and the Management Competency Acquisition and Supply.

Beasley et al. (2019) described the Technical Leadership Model developed by the INCOSE Institute for Technical Leadership and "mapped" its elements to the Professional Competencies. The Technical Leadership Model defines the state of "being a systems technical leader" in terms of six interdependent concepts that align with the Professional Competencies:

- Holding the Vision (Technical Leadership)
- Thinking Strategically (Technical Leadership)
- Fostering Collaboration (Negotiation, Team Dynamics, Facilitation)
- Communicating Effectively (Communications)
- Enabling Others to be Successful (Coaching and Mentoring, Ethics and Professionalism, Facilitation)

- Demonstrating Emotional Intelligence (EI)

While the Core Competencies, Technical Competencies, and some of the Integrating Competencies are traditionally addressed in engineering curricula and the SysE Management Competencies and others of the Integrating Competency areas are taught in engineering management programs, few of the Professional Competencies are addressed in either. While there have been panels and papers on this topic presented at the International Symposium over the past decade (which resulted in their inclusion in the 2018 Framework), these resources are difficult to access because they are not well indexed. A review of INCOSE webinars over the past five years shows that there were none that addressed the Professional Competencies. This is despite the importance of the Professional Competencies to SysE effectiveness. Clearly, the "soft skills" (or, as one reviewer called them, the "professional skills" noting that there is nothing soft about these skills – they are the hardest to learn!) that the Professional Competencies represent are areas in which systems engineers require developmental opportunities. A new INCOSE Working Group "Professional Competencies and Soft Skills" has been formed to address this gap.

Understanding systems engineers' strengths and weaknesses when it comes to the Professional Competencies, and being able to capitalize on strengths while minimizing weaknesses is key to project success. This paper discusses methods and techniques for improving one's competence in these competencies. First, though, there is a discussion of why the Professional Competencies are important to SysE effectiveness. Conclusions are drawn as to the importance of improving competence in the Professional Competencies and of the personal and organizational benefits that could accrue as a result of doing so.

Resources that this author has found useful for self-study are provided throughout this paper. Because the Professional Competencies and Soft Skills Working Group's website (INCOSE [a] n.d.) states that there is anecdotal evidence that generalized "soft skills" training is not fitting for training engineers, the focus of the methods provided is engineering-oriented or, at least, believed to be applicable across multiple disciplines.

The INCOSE Professional Competencies

In this section, each of the Professional Competencies is defined and their importance to SysE effectiveness is discussed.

Communications

The Communications Professional Competency is defined as "[t]he dynamic process of transmitting or exchanging information using various principles such as verbal, speech, body-language, signals, behavior, writing, audio, video, graphics, language, etc. Communication includes all interactions between individuals, individuals and groups or between different groups" (Presland, ed. 2018, pg. 45). "Communication plays a fundamental role in all facets of business within an organization, in order to: transfer information between individuals and groups to develop a common understanding and build and maintain relationships" (Presland, ed., p.45). Understanding of diversity-related differences in communication styles and preferences is essential for building consensus. Effective communication is key to project success.

Ethics and Professionalism

Professional (engineering) ethics comprise the personal, organizational, and corporate standards expected of systems engineers as well as the specialized knowledge, skills, and abilities used by systems engineers when providing services to the public. Professional responsibility is "the legal and moral duty of a professional to apply his or her knowledge in ways that benefit his or her client, and the wider society, without causing any injury to either" (businessdictionary.com n. d.).

Engineering does not have one uniform system of ethical conduct across the entire profession. The conduct of licensed Professional Engineers is governed by statues promulgated by the government entity that has given permission for the engineer to practice within its regulatory boundaries.

Most engineering professional societies, including INCOSE, have a Code of Ethics that governs fundamental principles and duties that apply to members' conduct as engineering professionals. A common feature of these codes is that the protection of the public interest, the environment, and the health and safety of those affected by the engineered product is paramount. Duties related to professional behavior with respect to one's clients, employers, and the profession itself is also a common element.

Engineers certified through a professional society – whereby a community of knowledgeable, experienced, and skilled representatives of the organization provides formal recognition that a person has achieved competency in specific areas as demonstrated by education, experience, and knowledge – may be bound by a Code of Ethics defined by the society, even if they are not members of the society.

Engineers working in government and industry, even if not licensed or certified, may be held to a standard of conduct by their employer. Such standards often rely on principles of business ethics rather than engineering ethics.

Ethics are just one aspect of professionalism, which refers to the conduct, behavior, and attitude of someone in a business environment (Virginia Polytechnic Institute and State University 2020). In addition to the taking of ethical and responsible actions, professionalism includes characteristics such as critical thinking and problem solving, initiative and accountability, and a respectful professional demeanor (Kokemuller 2018).

The preamble to INCOSE's Code of Ethics highlights the importance of ethical behavior in SysE, in particular, because of the unique nature of the discipline, which is highly integrative, often provides representation of stakeholders' interests other than those of the employer or client, and operates in international arenas where cultural dimensions such as value systems, beliefs and customs can vary widely (INCOSE [b] n. d.). Systems engineers are trusted to apply their knowledge and skills to make judgments and reach unbiased conclusions. It is important that the systems engineer always act ethically and responsibly in order to maintain trust and ensure professional standards are upheld and their wider societal obligations are met. Trust is central to leadership (Covey 2006) because without trust, there are no followers. Ethical behavior speeds up trust-building in relationships (Hosmer 1985), so plays a key role in building the trust needed by systems engineers with limited authority to motivate team members and others to achieve project success.

In addition, the preamble addresses the fundamental principles that systems engineers must use to uphold and advance the integrity, honor and dignity of the profession, fundamental duties to society and public infrastructure, and rules of practice for systems engineers.

Technical Leadership

Technical leadership in SysE combines the application of technical knowledge and experience with other professional competencies including communications and team dynamics, as well as other skills such as relationship management and accountability. Technical leadership encompasses, among other things, skills related to creativity and innovation in problem solving.

As noted previously, the INCOSE Technical Leadership Model (Godfrey, 2016) defines the state of "being a systems technical leader" in terms of six interdependent concepts: Holding the Vision; Thinking Strategically; Fostering Collaboration; Communicating Effectively; Enabling Others to be Successful; and Demonstrating Emotional Intelligence.

The technical areas in which a systems engineer must excel are encapsulated in the INCOSE Technical Competencies. In assessing technical leadership, as is done when reviewing Expert Systems Engineering Professional applicants, however, too often the emphasis is placed on technical knowledge and experience rather than on leadership in a technical area – the accent is placed on the wrong syllable, so to speak. Technical leadership should involve not only technical management, but also people management and project/program management.

As systems become increasingly complex and the environment becomes more competitive, technical excellence is critical; leadership in how to apply technical skills helps teams succeed in this environment.

Negotiation

In the Negotiation Professional Competency, systems engineers facilitate dialogue between parties having differences over one or more issues to achieve a beneficial outcome, which may apply to all parties or to just one of them.

Because systems engineers are the "glue" that hold system development efforts together, they are often at the leading edge of interacting with different groups of stakeholders and trying to gain agreement among them; negotiation skills are critical to this activity.

Team Dynamics

The Team Dynamics Professional Competency addresses the unconscious psychological forces that influence how a team behaves and performs; team dynamics are a function of the work itself, the personalities of the team members, and the work environment.

Good team dynamics can lead to better group and individual performance; on the other hand, bad team dynamics can cause conflict, be demotivating, and result in poor team performance. Bear and Wooley (2011) noted that scientific innovations are increasingly produced by team collaborations, making it all the more important that teams function effectively.

Facilitation

In the Framework, facilitation is defined as "the act of helping others to deal with a process, solve a problem, or reach a goal without getting directly involved" (Presland, ed. 2018, pg. 50). Facilitation is about helping people gain skills and knowledge; the job of a facilitator is setting up activities that enable people to learn from one another and build on their own knowledge, capitalizing on the learning cycle shown in Figure 1 (SeedsforChange.org n. d.), which says that people reflect on their experiences and generalize them to other situations then build on the new situations, gaining experience with them.

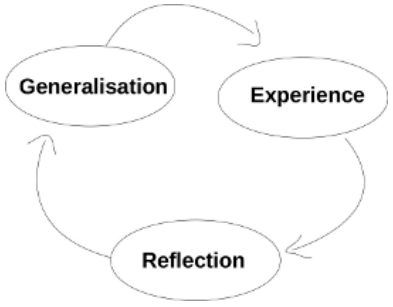

Figure 1. The Learning Cycle (From SeedsforChange.org n.d.)

Facilitation is considered a core competency for people who need to create and manage learning groups (Jelavic and Salter, 2014).

The facilitation competency is intimately related to the technical leadership competency – it is the "how" to the technical leadership competency's "what". In light of the fact that systems engineers often work in an environment in which they have a great deal of responsibility and accountability for delivering technical products with little authority with which to achieve the desired results, the systems engineer's leadership in facilitation becomes important to project success.

Emotional Intelligence

Rouse (2020) notes that the term emotional intelligence (EI) is often used as a synonym for people skills and soft skills. Salovey and Mayer (1990, pg.185) first defined emotional intelligence as "a set of skills hypothesized to contribute to the accurate appraisal and expression of emotion in oneself and in others, the effective regulation of emotion in self and others, and the use of feelings to motivate, plan, and achieve in one's life." Over the intervening years, others, including Presland (ed. 2018, pg. 51) have used simpler language: "the ability to monitor one's own and others' feelings, to discriminate among them, and to use this information to guide thinking and action." EI is conceived of as falling along four dimensions: perceiving emotion, using emotion to facilitate thought, understanding emotion, and managing emotion (Salovey and Mayer).

Development of EI enables individuals to glean information and ideas from others and allows connection with wider networks, breaking down barriers (Beasley et al. 2019). EI consists of five abilities – self-awareness, self-regulation, motivation, empathy, and social skills – that help individuals and organizations achieve higher productivity, more constructive and less stressful inter-

actions with colleagues, and better results on projects (Brauer 2019). These characteristic skills of EI are critical to SEs, who regularly interact with many diverse stakeholders.

Coaching and Mentoring

According to Keydifferences.com (2018) coaching is the process of training and supervising a person for a specific and short-term purpose, to improve their performance and develop skills, while mentoring is a counseling process carried out to provide encouragement, insight, and counseling to the mentee for the development of their career through a long-term informal relationship. Both employ one-on-one conversations in non-directive ways to achieve their objectives.

Coaching and mentoring support all of the SysE competencies in the framework; at the higher levels of each competency there is an expectation that those individuals will coach or mentor others in the competency. "Coaching and mentoring play an important role in the development of SysE professionals, providing targeted development and guidance, organizational and cultural insights. They represent learning opportunities for both parties, encouraging sharing and learning across generations and/or between roles (Presland, ed. pg. 52)."

The organization should also benefit from mentoring relationships between senior and more junior staff in the form of greater retention of staff engaged in mentoring, improved productivity, and enhanced communication (on both sides of the relationship). In a 2019 workplace survey, Wronski and Cohen found that about half of workers say they have a mentor at work, and those who do are significantly more likely to be happy with their jobs. They note that happier, more productive workers are valuable to the company because they tend to stay longer. Over 40% of workers who do not have a mentor said that they had considered quitting their job in the previous three months, compared with just 25% of those who do have a mentor.

Likewise, Lyman (2017) says that, while a mentoring relationship is primarily intended to benefit the mentee, mentoring can be equally as beneficial in building the mentor's experience, confidence, knowledge, and leadership capacity, as it is fulfilling. As an unbiased party, the mentor has the advantage of being able to see the whole picture, without getting caught in details or emotions that may hinder the mentee, so can offer advice that is clear and sound.

Methods for Improving Competence in the Professional Competencies

To succeed, Systems Engineers must possess exceptional professional skills. They must be able to identify the key stakeholders, understand and negotiate the problem space, not only be technically knowledgeable on the topic at hand but be able to coach others in applying that knowledge, be able to manage team dynamics, and be empathetic and able to communicate the message to all types of stakeholders. These are the skills embodied in the Professional Competencies; they can be learned!

Beasley et al. (2018) have noted that self-assessment of one's proficiency is particularly important for the Professional Competencies because only if one recognizes the absence of the competency or the need for improvement is one likely to seek development. As Holt and Perry (2011) discuss, individuals can use self-assessment against competency frameworks to identify needs for personal and professional development. Presland (ed., 2018) cautions, however, that individuals may

overstate their own competence in cases where they do not understand the full scope of the competency area and may understate their competence if they are not confident in it.

It is suggested that readers perform a self-assessment against the Professional Competency levels described in the Framework (Presland, ed. 2018) to help them decide how deeply to pursue the resources for improving the Professional Competencies described in this section.

Communications

There are a large number of communications models available in the literature. Two of them, the Precision Model and Multichannel Communications, are discussed below. These were selected, in the first case, because it is specific to developing system requirements and, in the second case, because of the move towards digital transformation in engineering.

Precision Model of Communications. Bostrom (1989) used the Precision Model of Communication, which is a generalized communication model that draws on communication behavior to facilitate effective communication between system developers and system users, to enhance the ability to develop shared, accurate, and complete system requirements. Meier (n. d.) states that, when people use imprecise language, there is ambiguity about what the real problem is. This, in turn, limits the ability to get actionable insights into the situation.

Bostrom's (1989) use of the Precision Model had a salutary effect on team dynamics, as the developers were better able to establish rapport with users and teams felt more productive and satisfied. Bostrom identified specific behaviors and guidelines to improve the requirements definition process which should, in turn, improve SysE effectiveness. These include challenging universals and generalizations (including generalizations about what one should or must do and what one cannot or must not do), clarifying verbs to gain insight into underlying actions, clarifying nouns to gain insight into who or what will be taking action, and challenging deletions such as too expensive, too much, and too many.

Meier (n. d.) is a good resource for those wishing to apply the Precision Model, as it contains a mnemonic for remembering the main points. He notes, however that one must exhibit good Emotional Intelligence (this author's words, not Meier's) by using it only when needed to clarify and not to question another's every statement, which would create friction within the team.

Multichannel Communications. IRP Commerce (2021) describe a four-step process for organizations wishing to adopt a traditional plus digital communications approach. Their comments are targeting toward marketing campaigns but are easily translated to a SysE context. They note that it is important to not think about having stand-alone traditional and digital strategies; rather, the approach must be integrated across channels.

The four steps of multichannel communications are: (1) Understand the audience – include determination of what platforms stakeholders use and how they prefer to interact with the program or project in the stakeholder analysis; (2) Choose the right channel – the choices should contribute to the overall goal of the communications campaign by driving stakeholder engagement and should also work well with the other channels to provide a consistent, unified message in the minds of the stakeholders (3) Shift the focus from awareness of the product or project from to engagement; and (4) Tailor the communications campaign – a multichannel communications strategy needs to have

content developed specifically for each channel; the content will be different, but the message needs to be consistent.

Ethics and Professionalism

Because they focus on problems, rather than subject matter, and are designed to facilitate immediate application in everyday life, analysis of case studies is an ideal method for developing adult learners. Although the method does not provide real experiences, it is personal and puts the burden of thinking through the problem on the learner and arouses their interest by making them active participants (Natural Resources Management and Environmental Department 1997).

This author (Hahn 2012) has used the case method to effectively develop engineers in engineering ethics. Sources of engineering ethics cases, with commentary by expert practitioners include:

- The American Society of Mechanical Engineers maintains an online "Ethics Center" at http://www.asme.org/NewsPublicPolicy/Ethics/Ethics_Center.cfm
- The Center for the Study of Ethics in Society at Texas A and M University (TAMU) provides a series of engineering case studies, with commentary by expert practitioners. These are available at http://ethics.tamu.edu
- The National Society of Professional Engineers (NSPE) has an Ethics Resources website, which includes a link to real case studies adjudicated by their Board of Ethical Review in reference to the NSPE Code of Conduct, at http://www.nspe.org/Ethics/EthicsResources/index.html

Many of the problems related to unprofessional behavior in the workplace are due to poor interpersonal skills and inappropriate communication styles, especially when communicating via electronic media. Because of the inter-relatedness of the Professional Competencies, improvements in the Communications and EI competencies should translate into improved professionalism.

Technical Leadership

Development of technical leadership skills revolves primarily around developing creative problem-solving skills. Using creative problem-solving techniques has a variety of benefits; it: (1) provides a structured approach; (2) results in several possible solutions; and (3) is collaborative and engages multiple stakeholders, thereby helping to ensure buy-in (Espy 2019). And, it is a skill that can be learned.

There are numerous examples of creative problem-solving methods. Three of them – the Osborn Parnes Creative Problem-Solving Process (as described by Espy 2019), Design Thinking (Ideo.org 2015), and TRIZ (Gadd 2011) – which are all either specifically developed to address engineering or technology problems or at least applicable in that context, are discussed below.

Osborn Parnes Creative Problem-Solving Process. According to Espy (2019), in its present instantiation the Osborn Parnes Creative Problem-Solving Process involves four categories of activities:

- *Clarify*, which involves determining the vision of the goal of the problem-solving process, gathering the data needed to fully understand the problem space, and generating a design

challenge after digging deeper into the problem and finding the root cause or real problem to focus on

- *Ideate* or generate many options for addressing the problem using techniques like brainstorming (which was developed by Osborn) to elicit ideas and affinity diagrams to organize them
- *Develop*, which involves generating solutions and evaluating them against selection criteria to determine which option is best
- *Implement*, which involves developing an action plan to implement the selected solution; the work breakdown structure should include both a responsibility matrix (who is going to do what and when) and a communication plan to help get stakeholder buy-in

Design Thinking. Design Thinking (DT) evolved from Human Centered Design, which is a process and a set of techniques used to create new solutions including products, services, environments, organizations, and modes of interaction (Ideo.org 2015). As Blanchard and Fabrycky (1998) note, design is the engine of SysE. Design must consider not only the technical aspects of the system, as reflected by the traditional engineering disciplines with their concerns about materials and the forces of nature, but also the needs of people, including economic, ecological, political, social, cultural, and psychological factors that may impose constraints on the design.

Engineering has always been concerned with design to benefit people (Blanchard and Fabrycky 1998), but engineering and DT have different starting points: Engineering starts with technology (concerns with feasibility, technology readiness) and business issues (viability), while DT starts with people, bringing their needs, dreams, and behaviors to the forefront of the design process (Ideo.org 2015). DT involves multi-disciplinary teams, and is likely to engage social scientists, lawyers, and ethicists in addition to discipline engineers; the inclusion of multiple disciplines is key to achieving the kind of divergent thinking needed to ensure that many possible solutions are explored before converging on a preferred solution (Robson 2002).

As explained by Ideo.org (2015), DT includes five phases: (1) *Empathize* – gather and organize data from the perspectives of the people who will be affected by the product; (2) *Define* – distill the background information to identify the issues and develop a clear picture of what the project is and what it must accomplish; (3) *Ideate* – brainstorm, discuss, and sort multiple solutions; (4) *Prototype* – rapidly build a selected design to determine feasibility and proof-of-concept; and (5) *Test* – find the faults and improve the prototype, ideally incorporating direct stakeholder feedback, to arrive at the final solution.

DT begins with trying to understand the problem space and the stakeholders whose needs must be satisfied using qualitative methods such as interviews and focus groups, in addition to reviews of project documents such as the Request for Proposals or Concept of Operations, to obtain data about business, system, and stakeholder requirements.

A Design Challenge serves as the initial problem statement, which is reframed throughout the project as the design team gains additional knowledge about the problem. Rather than writing quantitative requirements and developing verification metrics, DT uses content clustering analysis to distill themes and, from them, to develop qualitative vision statements for each class of stakeholders. A synthesized vision statement that addresses the key characteristics or design criteria that a successful solution must meet is the basis for the design.

DT uses brainstorming exercises structured around the design criteria reflected in the overall vision statement as the primary method for generating potential solutions. Once all ideas have been exhausted, solutions are categorized into like groups, the list of solutions is reduced by removing those thought to be infeasible, and the remainder are analyzed to identify the best options (Muzio 2011). Design Thinking does not employ formal trade studies, instead using this initial evaluation of solutions followed by rapid evolutions of prototyping and testing to evolve the final design.

Design Thinking is not relevant only for "soft" systems. It is relevant in any situation where disruptive technologies have societal impacts. Take ride-sharing services like Uber and Lyft, which have supplanted taxi companies in many areas (Peppers 2016). Peppers notes that these services will almost certainly be supplanted by autonomous vehicles (AV), but this poses societal questions – like what happens to personal car ownership, how drivers will earn a living, how prospective passengers will assess the safety of the technology, and whether the passengers will be negatively affected by the lack of engagement with other human beings – any of which could affect the speed and depth of AV adoption. DT methods could prove useful in evaluating and perhaps mitigating the human impacts of these technologies.

DT taps into the Technical Leadership Competency, which involves problem solving and innovation as important skills and which combines the application of technical knowledge and experience with other professional competencies as well as skills such as problem solving, relationship management, accountability, and creativity and innovation.

Due to its use of qualitative elicitation and analysis methods, DT relies heavily on the soft skills that are embodied in the Professional Competencies of Communications, Ethics and Professionalism, Negotiation, Team Dynamics, Facilitation, and Emotional Intelligence (EI).

TRIZ. The TRIZ methodology, a Russian problem-solving method whose name translates to the "theory of inventive problem solving" in English, provides principles for resolving contradictory requirements (Gadd 2011)[2]. Whereas conventional solutions typically trade off one contradiction against another, the inventive solutions developed with TRIZ allow one to solve several contradictions simultaneously (Wikipedia 2020).

Like the previously discussed creative problem-solving methods, TRIZ requires both creative and logical, systematic thinking but that is accomplished very differently in TRIZ than in the other methods. TRIZ is essentially a problem-solving toolkit, developed by engineers for engineers. The main tools are briefly described here. Readers needing "how to" information are referred to Gadd (2011), who provides numerous problem-solving case studies, examples, and exercises.

TRIZ was developed from a comprehensive analysis of patents for technical systems to find out how the innovation had taken place. According to Wikipedia.org (2020), while conducting this analysis, Genric Altshuller, the original developer of TRIZ, realized that a problem requires an innovative solution in cases where there is an unresolved contradiction between parameters (that is, where improving one parameter harms another parameter). From this observation, Altschuller developed the concept of technical contradictions and, later, that of physical contradictions. His

[2] All TRIZ references come from Gadd (2011) unless otherwise cited.

analysis focused on identifying the kinds of contradictions that had been resolved by the invention and how that was accomplished. From that, he developed a set of inventive principles and a matrix of contradictions where the rows indicate system functions or parameters that one wants to improve, the columns contain typical undesired results, and the cells contain the inventive principles that have been most commonly used to resolve the contradiction. The analysis of the contradiction, the search for one or more principles that will help resolve it, and the pursuit of an ideal solution are the key elements of TRIZ.

Ideality, which is defined as the sum of all benefits (desired outputs – needs/requirements) divided by the sum of all costs (all inputs) and the sum of all harms (undesired outputs) combined, is the aim of all problem solving. In this context, needs, benefits, and functions and features have specific meanings: a need or requirement refers to the lack or want of something; a benefit is a good output that fulfills a need – a benefit only describes what is wanted and does not offer a solution; functions, features, and resources tell the way benefits are provided. Problem solving, then, is providing the right benefits to more exactly meet needs by providing or improving functions, features, or resources.

In defining a problem, one first looks at the ideality of the current system and compares it to the ideality of the desired system. The problem is defined in terms of the gaps between what is wanted (requirements) and what is currently available (system features, functions, and resources).

After a problem has been identified and defined, TRIZ involves the application of the "Prism of TRIZ" which takes the factual problem, generalizes the inherent contradiction and compares it to other similar conceptual problems, locates relevant conceptual solutions, and arrives at a factual solution by analyzing and combining the conceptual solutions while systematically "trimming" or simplifying them without losing functionality. Gadd (2011) has shown that this process results in far more solution options than would have been generated using simple brainstorming – use of the Prism of TRIZ provides access to routes to find solutions that are not known to the people solving the problem but are known elsewhere.

There are four main tools in TRIZ plus numerous other techniques that help with their implementation. The four main tools are:

- 40 Principles for solving contradictions (using the contradictions separations matrices)
- Eight trends of evolution, which are used for future system development
- Effects, which are the scientific and conceptual answers to questions about how to achieve the functions, parameters, and transformations needed to solve the problem; there are about 2500 effects
- About 100 standard conceptual solutions to solve system problems; these are based on scientific principles known to have solved similar problems

The steps involved in executing the Prism of TRIZ are relatively straightforward: after performing an ideality audit to understand the needs, the problem is stated in simple, non-specific terms as the function, parameter, or transformation that is wanted: the problem statement is phrased as a

question (e. g., How can we…?); the effects database[3] is used to find all known conceptual solutions; and, using TRIZ tools like Thinking in Time and Scale, the solutions are sorted into combinations that resolve contradictions, insufficiencies, and harms.

TRIZ also includes team building tools (some of which are called creativity triggers) that encourage everyone on a team to generate solutions. One of these, Smart Little People, has team members invent imaginary beings that represent different parts of the problem. These beings are built on empathy, through creating a personal analogy to the little people.

As the founder of Oxford Creativity, Karen Gadd has successfully introduced TRIZ to many INCOSE Corporate Advisory Board organizations including Airbus, Rolls Royce and BAE Systems. Her book contains case studies from all three companies.

Discussion. Both the Osborn Parnes Creative Problem-Solving Process (Espy 2019) and Design Thinking (Ideo.org 2015) use a balance of divergent and convergent thinking to arrive at a solution. Both recommend brainstorming as the method of choice for divergent thinking. TRIZ also uses both divergent and convergent thinking, but does so in the opposite order from the other two methods: it first focuses down (converging) from a real factual problem to a simple conceptual problem then locates conceptual answers that are expanded back (diverging) to a few conceptual solutions and then to all possible factual solutions (Gadd 2011).

Altshuller thought that Osborn's style of brainstorming was useful for simpler problems – those with apparent solutions or those making minor improvements to existing systems – but developed TRIZ tools to structure problem understanding, analysis, and solution for harder problems – those making major improvements, those to develop new concepts (new combinations of technologies to produce new solutions and materials), and those where discovery (new science) is needed (Gadd 2011).

All three methods emphasize gaining a thorough understanding of the problem space, framing needs, and identifying gaps before moving into solution space. Recognizing that engineers like to jump to solutions, Gadd (2011, pg. 52) recommends using a "BAD Solutions Park" to capture solution concepts that come up during the problem understanding and analysis phases so that they are not lost. She calls them "bad" because, with the problem not being fully understood, these ideas will likely not completely solve the problem, though they may be useful as part of the final solution.

Because Design Thinking (Ideo.org 2015) and TRIZ (Gadd 2011) have a focus on empathy, they might be helpful in increasing Emotional Intelligence. TRIZ also has tools for improving Team Dynamics.

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[3] Oxford Creativity (n. d.) provides a freely accessible effects database at www.TRIZ4engineers.com that returns lists of standard solutions, with definitions, when queried about the function, parameter, or transformation that needs resolution.

Negotiation

Boehm and Egyed (1998) reported successfully using the WinWin negotiation model shown in Figure 2 in requirements development efforts. Win conditions reflect stakeholder needs and concerns with the system under development. Readers familiar with the popular games Minecraft, League of Legends, and Clash Royale, to name a few, will be familiar with win conditions as one or more specific strategies to achieve victory. Strategies may be primary, secondary, or backup and may also reflect possible but unlikely sequences of events (Hearthstone 2018).

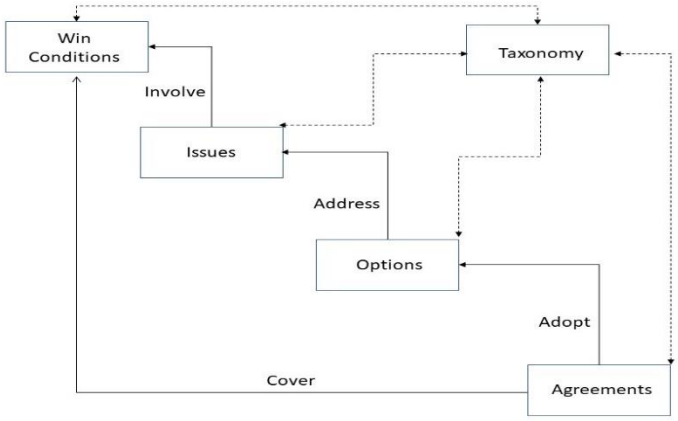

Figure 2. WinWin Artifact Relationships and Taxonomy (from Boehm and Egyed 1998)

It is not difficult to imagine what the win conditions for these games are. Unfortunately, Boehm and Egyed (1998) did not specify what the win conditions might have been (and the link to the full report, where the win conditions presumably could be found, was broken). Egyed and Boehm (1997), writing about the same exercise, say that they suggested a set of stakeholder goals and implementation options for the participants to use while negotiating a satisfactory set of system requirements, but did not detail what they were. Participants were not bound to use these win conditions and solution options. Given the nature of the project (a library archiving project addressing a variety of media), the win conditions would probably be things like "Stakeholders need to be able to search for maps by country, region, and date of issue."

If a win condition is not controversial, it is adopted by an agreement; otherwise, it becomes an issue that that documents the conflict (usually involving personnel or other resources) that must be resolved (Boehm and Egyed 1998). Options are alternative solutions, suggested by stakeholders, to resolve issues. The model can be used with either spiral (iterative) or waterfall processes, as it incorporates elements of both of these methods as well as other models. Agreements are used to adopt an option, thus resolving the issue.

The WinWin model is also linked to a domain-specific taxonomy, structured around the tables of contents of the requirements documents for the various projects, allowing participants to track their artifacts to the taxonomy and ensure that there is adequate coverage of the domain (Boehm and Egyed 1998).

Negotiation outcomes were graded against a Life Cycle Objective (LCO), which included requirements, operational concept, architecture, and life cycle plan, among other artifacts (Boehm and Egyed 1998). Boehm and Egyed reported the following results:

- Most of the win conditions were not controversial (that is, did not involve issues) and most of the issues were not coupled to other issues and were easy to resolve; this suggests that negotiation models should focus on handling both simple and complex relationships (where complexity is defined in terms of the number/proportion of win conditions involved in issues, the number/proportion of issues with multiple options, and the proportion of win conditions to options and agreements)
- The LCO package quality could be predicted by team experience, iterative negotiation, and efficiency in producing artifacts; there was a strong positive correlation between iterative negotiation and LCO grade and a strong negative correlation between a waterfall approach and LCO grade. Not surprisingly, teams with high experience produced better quality LCO packages, in part because they were more efficient than teams with low experience
- The duration of negotiation was negatively related to the quality of the LCO, with teams that took longer having lower quality artifacts. This is moderated by another variable, the amount of effort put into the negotiation, which was more important than duration to overall quality. This suggests that negotiation schedules can be compressed, with the caveat that there must be sufficient team experience and domain knowledge to support rapid development
- Stakeholder engagement varied throughout the projects, with users and customers being most engaged in early stages and developers being more engaged in later stages, suggesting that the use of Integrated Project Teams would be beneficial

According to Boehm and Egyed (1998), the WinWin method increased cooperation, focused participants on key issues, and reduced friction (especially if the group norm was to give feedback, have collective responses, and be flexible), and equalized participants, suggesting that the WinWin method improved team dynamics.

Following on the observation about using an iterative approach, Boehm and Egyed (1998) suggest using concurrent prototyping and negotiation.

Team Dynamics

The goal of managing team dynamics is the enablement of high-performing teams (HPTs), which the Society for Human Resources Management (SHRM 2022) defines as a group of goal-focused people with specialized expertise and complementary skills who work collaboratively to produce superior results. SHRM makes the point that not all groups are teams – teams are committed to a common purpose, performance goals, and approach. HPTs typically develop their own norms and standards – things like open communication, early conflict resolution, regular assessment of both individual and team performance, and a strong results-focused work ethic – then hold themselves and other team members accountable for upholding them. Further, members are empowered to make choices within defined decision-making boundaries.

SHRM (2022) describes four stages in the evolution of team dynamics: (1) Forming – people are trying to get to know one another and the organization and are not yet committed; (2) Storming – team members challenge the leader and one another and the leader is focused on managing conflict and goal-setting; (3) Norming – individuals start to appreciate each other and begin working together; the leader acts as a facilitator, as described in the section on facilitation below; and (4) Performing – the team is fully functional and working toward shared goals.

During the forming stage it is useful to have group members assess themselves using a tool like the DISC assessment which examines how an individual ranks in four areas of behavior – Dominance, Influence, Steadiness and Conscientiousness – which everyone has, but at varying strengths depending on the individual (Robbins 2021). People with a high Dominance score tend to be direct, results-oriented, competitive, and decisive problem-solvers. Those with a high Influence score tend to be persuasive, enthusiastic, and optimistic. Those with a high Steadiness score tend to be patient, stable, understanding team players. Those with a high Conscientiousness score tend to be analytical, precise, and objective. In forming teams, it is desirable to have people who represent each of the four areas.

The DISC assessment provides a common language that people can use to understand themselves and others (Robbins 2021). It is beneficial because identifying the communication needs of the individuals on a team facilitates better conflict management and overall stronger cohesiveness. A free copy of the assessment tool is available at: https://www.tonyrobbins.com/disc/

People define themselves in terms of many variables – gender, ethnicity, affiliations, etc. – which collectively comprise their identity (Neeley 2015). A person's behavior may mean different things depending on their identity; misperceptions about the meaning of behavior is a major source of social distance and leads to mistrust. Leaders of multi-cultural teams must avoid making assumptions about what behaviors mean. They should instead ask questions and provide answers as a way of establishing two-way communication, thereby instructing but also facilitating to help team members understand their observations of one another's behavior and gain insights into their identities.

Neeley (2015) says that the major factor that distinguishes teams that work well from those that do not is social distance; high social distance results in less successful teaming because team members struggle to develop effective interactions. She proposes the SPLIT framework – structure, process, language, identity and technology – each of which can be a source of social distance, as a method for dealing with dysfunction in multi-cultural or dispersed teams.

The structural dimensions that contribute to social distance are the locations and number of sites where team members work and the number of workers at each site (Neeley, 2015). Neeley says that the fundamental issue here is the perception of power, with the majority being seen as more powerful than the minority; collocated members of the majority may also have a strong allegiance to one another and not much allegiance to other team members. According to Neeley, to counter power imbalances, the leader must:

- Reinforce the message that the team is a single entity and encourage (enforce?) sensitivity to cultural differences
- Remind the team of their common purpose and channel their efforts toward business goals

- Be available to the team and provide team members with constructive feedback as well as messages reinforcing the point that their contributions matter

Empathy helps reduce social distance (Neeley, 2015). Leaders must build "deliberate moments" into their processes for virtual meetings to help team members build empathy (Neeley); these include:

- Providing feedback on routine interactions among team members and encouraging "reflected knowledge" or an awareness of how others see oneself (EI again)
- Factoring unstructured time into the beginning of meetings and encouraging informal discussions about work and personal matters to allow team members to get to know one another better
- Encouraging disagreement about the team's tasks and the process by which those tasks get done and framing this as an opportunity to contribute ideas (that is, brainstorming)

Multi-cultural teams are likely to experience differences with respect to fluency with the chosen common language, which can lead to heightened social distance and perceived power imbalances (Neeley 2015). To counteract this, leaders must enforce three rules for communicating in meetings:

- "Dial down dominance" of fluent speakers by having them slow their speaking pace; use fewer idioms, slang phrases, and cultural references; limit air time; seek confirmation of the listener's understanding; and listen actively
- "Dial up engagement" of less fluent speakers by ensuring that they contribute, discouraging them from reverting to their native language, encouraging them to seek confirmation that they are being understood, and empowering them to speak up if they have not understood something
- Balance participation to ensure equal time for speaking and listening; draw out contributions from all team members, especially from those who are less fluent; and clarify and interpret content

Technology can either increase or decrease social distance (Neeley 2015). As Jelavic and Salter (2014) noted, different cultures have different preferences for modes of communication, with high uncertainty avoiding cultures preferring written communications. In deciding which mode of communication to use, leaders should consider the following three issues: Whether

- To use instant communication technologies, which are valuable when trying to persuade others to one's viewpoint, or delayed technologies, if the purpose is merely to convey information
- Multiple platforms should be used to ensure that messages are understood and remembered
- The leader models the expected behavior regarding communication technology use and responsiveness to communications for team members

Neeley (2015) says that leaders must attend to all five aspects of the SPLIT framework if they are to manage social distance effectively and maximize team performance. She notes that decisions about structure create opportunities for good process, which can mitigate language fluency differences and identity issues. Leaders who do these things while employing technology appropri-

ately to manage team communications are likely to see social distance shrink, resulting in respectful interactions that drive innovation.

Facilitation

The Facilitation Professional Competency is about facilitative leadership and enablement, which involves giving the facilitated group everything – tools, training, information, people resources, and structures and processes – they need to perform their tasks to the best of their abilities and creating an environment that allows them to perform optimally (Zavvy 2022).

Zavvy (2022) gives eight tips for shifting from mere engagement of individuals and teams to enablement as shown in Table 1. SHRM (2022) gives similar tips, also shown in Table 1, for helping teams move through the evolutionary phases quickly. The advice provided is very similar – both address goal setting (SMART goals – Specific, Measurable, Attainable, Realistic, and Time-bound); having the right resources; work environment; removing roadblocks; professional development; and empowerment and servant leadership.

Emotional Intelligence

Self-awareness of one's patterns of behavior and their impact on others is a key aspect of emotional intelligence. The DISC assessment discussed previously is a tool that people can use to understand themselves and others (Robbins, 2021).

A Google search on the phrase "How to improve emotional intelligence" yielded over 25 million hits. Many of these were for companies selling training programs, but there were also a large number that give tips for improving one's EI. Harvard Professional Development ([HPD] 2019) recommends taking a 360-degree emotional intelligence assessment as a way to gain insight into one's EI-components and impact on others. HPD notes that developing one's EI is an ongoing process (that can continue for as long as the person wants to improve their EI [Stahl 2018]) and one that differs from person to person. HPD offers three creative suggestions of things to do to improve EI:

- Recognize one's emotion and name the feelings, which helps to temper reactivity to the feelings
- Ask for feedback from managers, colleagues, friends, and family regarding how well one handles conflict, empathizes, and deals with difficult situations (that is, the aforementioned 360-degree assessment)
- Read stories with complex characters to gain insight into their thoughts, motivations, and actions, which may help improve empathy and enhance social awareness

Ni (2014) describes six "abilities" that one needs to improve to effect better EI and provides tips for developing them:

- The ability to reduce negative emotions, such that they do not influence how one feels about a situation by avoiding personalizing another person's behavior and providing oneself with multiple options for any given situation so that there are strong alternatives for moving forward, is the top priority for those wishing to improve their emotional intelligence. Stahl (2018) also has this as her number one item for improving EI

Table 1. Zavvy's and SHRM's Views of Facilitation

Zavvy (2022)	SHRM (2022)
Set SMART goals & communicate benefits	Keep purpose & goals relevant & communicate
Understand available resources & how individuals use them & identify gaps	Ensure individuals have the right skills & maintain & enhance them
Enable an open, collaborative work environment; invite open discussion & collaboration	Build commitment
Optimize workflows & processes	Manage external relationships to remove roadblocks
Tailor learning & development programs	Provide development opportunities
Empower team autonomy	Work alongside team members
Have teams build a knowledge base	

- The ability to stay calm and manage stress, which can make the difference between being assertive versus reactive. Ni suggests splashing cold water on one's face and getting fresh air as a way to reduce anxiety. He also suggests engaging in intense aerobic exercise when one is fearful, depressed, or discouraged. Stahl (2018) recommends identifying one's stressors and engaging proactively to have less of them
- The ability to be assertive, express difficult emotions, and set appropriate boundaries. Ni describes the XYZ technique for dealing with difficult emotions – I feel X when you do Y in situation Z. This author uses a similar technique in conducting lessons learned exercises – I would do X again because it got positive result Y in situation Z or I would not do A again because it got negative result B in situation C
- The ability to stay proactive when interacting with a difficult person. Tricks for staying proactive include counting to ten or taking a time out before reacting, putting oneself in the other person's shoes (seeing the situation from the other person's perspective, which Stahl [2018] calls practicing empathy), and identifying and asserting consequences for the other person if that person does not shift to a more positive position (Ni)
- The ability to bounce back from adversity, which Ni says can be accomplished by asking oneself constructive questions based on learning and priorities to gain the proper perspective to help tackle the situation at hand. Stahl (2018) notes that how one reacts to adversity either sets up success or creates a failure mode

- The ability to express intimate emotions in close, personal relationships and to respond to the intimate person when they do the same. This is key to maintaining the intimate relationship

Stahl (2018) includes being mindful of one's vocabulary and using specific language to communicate deficiencies, which improves the likelihood of addressing the problem, in her tips for improving emotional intelligence. This is just another example of the interrelatedness of the Professional Competencies – in this case, EI and Communications.

Coaching and Mentoring

Coaching is another area having a large number of Google search hits, almost all of them for training providers. One exception is Mattone (2017), who provides an outline of the coaching process, which begins with a meeting between the coaching client and the sponsoring executive team to discuss the goals of the coaching relationship, gain context and background information, and discuss the proposed roadmap of how to get there. Mattone suggests conducting a 360-degree assessment with the client's key stakeholders and having the client also conduct a self-assessment of their leadership strengths and areas for improvement.

The next step in the coaching relationship is helping the client create a Core Purpose Statement that captures the essence of the leader the client wants to become, which qualities they must develop in order to do so, and what they want to accomplish (Mattone 2017).

The client then meets with their stakeholders to share their purpose statement and solicit feedback, which is then used to finalize the client's leadership development plan (Mattone 2017). The coach provides ongoing support and guidance to help the client measure the progress they are making toward their development goals.

The coaching relationship ends when the client reaches their development goals (Keydifferences.com, 2018).

Cox (2016) offers the following tips on how to be a good mentor:

- First, know yourself – think about your own style and readiness and the kind of commitment you want to make
- Set expectations with the prospective mentee at the beginning – both the mentor and mentee will have expectations, which need to be clear and congruent if the relationship is to be successful
- Get to know your mentee on a personal level – use active listening, ask open-ended questions to dig deeper, and act as a sounding board
- Know when to wait before giving feedback – if the right information isn't available or the experience or emotional response is not conducive to giving advice, pause to allow time to gather more information, talk to other resources, and formulate an appropriate response
- Improve your emotional intelligence
- Do not make assumptions about or apply stereotypes to the mentee

- Be open to sharing your own mistakes and failures – this helps build trust and makes it more likely that the mentee will share theirs
- Celebrate the mentee's achievements
- Both the mentee and the mentor give to and take from the relationship; mentors should give more than they take
- Provide resources for the skills the mentee needs to develop
- Have a long-term mindset
- Be a positive role model

The MindTools Content Team (n.d.) offers the GROW Model for structuring coaching and mentoring sessions. GROW stands for Goal, (Current) Reality, Options, and Will. GROW involves four steps: (1) Establish a SMART goal for a behavior that the client wants to change; (2) Look at the Current Reality to be sure that the starting point is well understood and that all the information needed to enable attainment of the goal is available; (3) Brainstorm all the possible options and help the client decide on the best one; and (4) Help the client establish the will to achieve the goal – that is, commit to take specific actions that will help them move forward – and set a time-frame for reviewing their progress.

The MindTools Content Team (n.d.) notes that the two most important skills for a coach are the ability to ask good questions and to use active listening techniques. Depending on the situation and the relationship between the coach/mentor and the client or team member, the coach may serve solely as a facilitator or may offer advice or direction.

Summary and Conclusions

Proficiency in the Professional Competencies is a critical factor in the overall success of SysE efforts. As Beasley et al. (2018, pg. 314) state:

> *"Wherever applied, the nature of the systems approach, with its holistic big picture view, means influencing, communicating between and understanding people will always be key. People will depend on their professional competencies as much as their technical ones. The systems engineering profession must recognize that, and look to provide guidance/advice on how to improve/develop them in the individuals in the profession."*

Because we know the importance of the Professional Competencies to SysE success from the Competency Framework, we believe that improving competence in the Professional Competencies should improve SysE effectiveness and overall project performance. Specifically, improving in

- Communications helps develop common understanding and build relationships
- Ethics and Professionalism ensures that trust is maintained and professional standards are met
- Technical Leadership helps teams meet high levels of technical excellence
- Negotiation enables gaining agreement among diverse groups of stakeholders
- Team Dynamics improves overall team performance
- Facilitation makes it easier for team members to achieve agreed upon goals

- EI allows for success in interacting with colleagues and stakeholders and in managing conflicts and stress
- Coaching and Mentoring provides for targeted development and guidance

In looking through a number of websites that provide career advice for engineers, common themes emerged regarding what employers look for in their engineers both when making hiring decisions and when making promotion decisions – things that differentiate them from being "just" an engineer. In addition to technical competence, employers want engineers who are:

- Good communicators, able to translate their specialized knowledge into terms that people outside their field can understand
- Resilient, exhibiting interpersonal adaptability among different kinds of people, problems, and situations
- Team players, able to work collaboratively with others
- Technical leaders
- Problem solvers, able to work creatively to innovate to solve real-world problems

As a result, systems engineers have an imperative to develop and continuously improve their competence in the Professional Competencies. In a 2021 paper, this author (Hahn 2021) explained how various Systems Engineering Competencies build resilience due to their relationships to Spacey's (2017) personal resilience characteristics. Because of the close relationship between personal resilience traits and the Professional Competencies specifically, developing oneself in the Professional Competencies should further the development of personal resilience. This, in turn, should enable the ability to overcome adversity, whether professional or personal.

In addition, developing in the Professional Competencies will result in engineers who are more well-rounded, have enhanced EI and interpersonal skills, and have improved their overall engineering abilities (Ryan, n.d.). This should enable the engineer to obtain more interesting and challenging assignments, get along well with their co-workers and clients, and perhaps even progress to higher levels in their careers.

Critical self-assessment of one's own competencies is key for development. By self-assessing one can tailor development to one's own needs rather than taking a tick-the-box approach, which could lead to the development activities being unproductive for that individual. There is a caution, though, that individuals may overstate their competence when don't understand the full scope of the competency area or understate it when they're not confident in it.

This paper has provided promising strategies for how engineers can improve their competence in the soft skills, emphasizing those methods that cross-cut several of the highly interrelated competency areas. While studying these methods is important, it will not necessarily lead to performance improvements – practice is key! Engineers should look for opportunities to exercise their soft skills. Engineering provides a lot of opportunity in this arena. For example, the empathy component of EI as it pertains to engineering is about being in tune with a customer's needs. In addition, engineering is fundamentally about problem-solving, which means finding new ways to apply existing knowledge; this requires creativity and innovation.

Because the INCOSE competencies are highly interrelated, developing in the Professional Competencies might also result in improvements in other competency areas. For example, develop-

ment in ethics and professionalism, which requires critical thinking, may also result in improvement in the Critical Thinking Core Competency. A partial mapping of the interrelationships among the various competencies was presented at the 2021 INCOSE International Symposium. That presentation is available upon request from this author.

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