Developing Individuals

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Developing each individual's systems engineering (SE) competencies is a key aspect of enabling individuals. The goal may be to develop competency in a broad range of SE competencies or a single aspect of SE, and it is important to know exactly which SE competencies are desired. This article describes strategies to develop SE competencies in individuals.

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Closing Competency Gaps

Delivering excellent systems that fulfill customer needs is the primary goal of the organization. Developing the

''capability *to deliver such systems is a secondary goal, and while necessary, is not sufficient. To attain both of these goals, the organization must assess itself and effect a strategy to identify and close competency gaps.*

To identify competency gaps, an organization may take two basic steps:

1. Listing desired competencies, as discussed in Roles and Competencies; and
2. Assessing the competencies of individual systems engineers, as discussed in Assessing Individuals.

Models useful for listing competencies include the International Council on Systems Engineering (INCOSE) United Kingdom Advisory Board model (Cowper et al. 2005; INCOSE 2010), the ENG Competency Model (DAU 2013), and the Academy of Program/Project & Engineering Leadership (APPEL 2009) model (Menrad and Lawson 2008).

Once the organization knows the SE competencies it needs to develop to close the competency gaps it has identified, it may choose from the several methods (Davidz and Martin 2011) outlined in the table below.

Table 1. SE Competency Development Framework.
(SEBoK Original)

Goal	Objective	Method
PRIMARY GOAL = Delivery of excellent systems to fulfill customer needs	Focus on successful performance outcome	Corporate intiatives
	Focus on performance of project team	Team coaching of project team for performance enhancement

SECONDARY GOAL = Competency to deliver excellent systems to fulfill customer needs	Develop individual competency	Training courses
		Job rotation
		Mentoring
		Hands-on experience
		Develop a few hand-picked individuals
		University educational degree program
		Customized educational program
		Combination program - education, training, job rotation, mentoring, hands-on experience
		Course certificate program
	Ensure individual competency through certification	Certification program
	Filter those working in systems roles	Use individual characteristics to select employees for systems roles
	Ensure organizational competency through certification	ISO 9000
	Develop organizational systems competency through processes	Process improvement using an established framework
		Concept maps to identify the thought processes of senior systems engineers
		Standarize systems policies and procedures for consistency
		Systems engineering web portal
		Systems knowledge management repository
		On-call organizational experts
		Rotating professor who works at company part-time and is at university part-time

System Delivery

Some organizations mount initiatives which focus directly on successful system delivery. Others focus on project team performance, in some cases by offering coaching, as a means to ensure successful system delivery.

One example of the latter approach is the performance enhancement service of the US National Aeronautics and Space Administration (NASA) Academy of Program/Project & Engineering Leadership (APPEL), which assesses team performance and then offers developmental interventions with coaching (NASA 2010).

Organizations pursue multiple paths towards developing the capability to deliver excellent systems, including:

- developing the competency of individuals;
- developing the competency of the organization through processes (Davidz and Maier 2007); and
- putting measures in place to verify the efficacy of the selected methods.

Individual Competency

An organization may choose a combination of methods to develop individual systems competency. General Electric's Edison Engineering Development Program (GE 2010) and Lockheed Martin's Leadership Development Programs (Lockheed Martin 2010) are examples among the many combination programs offered within companies.

Whether or not the program is specifically oriented to develop systems skills, the breadth of technical training and experience, coupled with business training, can produce a rich understanding of systems for the participant. Furthermore, new combination programs can be designed to develop specific systems-oriented skills for an organization.

Methods for developing individual competency include:

- **classroom or online training courses**, a traditional choice for knowledge transfer and skill acquisition. Here, an instructor directs a classroom of participants. The method of instruction may vary from a lecture format to case study work to hands-on exercises. The impact and effectiveness of this method varies

considerably based on the skill of the instructor, the effort of the participants, the presentation of the material, the course content, the quality of the course design process, and the matching of the course material to organizational needs. These types of interventions may also be given online. Squires (2011) investigates the relationship between online pedagogy and student perceived learning of SE competencies.

- **job rotation**, where a participant rotates through a series of work assignments that cut across different aspects of the organization to gain broad experience in a relatively short time.
- **mentoring**, where a more experienced individual is paired with a protégé in a developmental relationship. Many organizations use mentoring, whose impact and effectiveness vary considerably. Success factors are the tenable pairing of individuals, and the provision of adequate time for mentoring.
- **hands-on experience**, where organizations provide for their engineers to get hands-on experience that they would otherwise lack. A research study by Davidz on enablers and barriers to the development of systems thinking showed that systems thinking is developed primarily by experiential learning (Davidz 2006; Davidz and Nightingale 2008, 1-14). As an example, some individuals found that working in a job that dealt with the full system, such as working in an integration and test environment, enabled development of systems thinking.
- **selecting individuals** who appear to have high potential and focusing on their development. Hand-selection may or may not be accompanied by the other identified methods.
- **formal education**, such as a university degree program. A growing number of SE degree programs are offered worldwide (Lasfer and Pyster 2011). Companies have also worked with local universities to set up customized educational programs for their employees. The company benefits because it can tailor the educational program to the unique needs of its business. In a certificate program, individuals receive a certificate for taking a specific set of courses, either at a university or as provided by the company. There are a growing number of certificate programs for developing systems competency.

Individual Certification

Organizations may seek to boost individual systems competency through certification programs. These can combine work experience, educational background, and training classes. Certifications are offered by local, national, and international professional bodies.

SE organizations may encourage employees to seek certification from the International Council on Systems Engineering (INCOSE 2011) or may use this type of certification as a filter (see **Filters**, below). In addition, many companies have developed their own internal certification measures. For example, the Aerospace Corporation has an Aerospace Systems Architecting and Engineering Certificate Program (ASAECP). (Gardner 2007.)

Filters

Another approach to developing individual competency is to select employees for systems roles based on certain characteristics, or filters. Before using a list of characteristics for filtering, an organization should critically examine:

1. how the list of individual characteristics was determined, and
2. how the characteristics identified enable the performance of a systems job.

Characteristics used as filters should:

- enable one to perform a systems job,
- be viewed as important to perform a systems job, or
- be necessary to perform a systems job.

A necessary characteristic is much stronger than an enabling one, and before filtering for certain traits, it is important to understand whether the characteristic is an enabler or a necessity.

Finally, it is important to understand the extent to which findings are generally applicable, since a list of characteristics that determine success in one organization may not be generalizable to another organization.

Organizational Capability

Once an organization has determined which SE capabilities are mission critical (see Deciding on Desired Systems Engineering Capabilities within Businesses and Enterprises), there are many different ways in which an organization can seek to develop or improve these capabilities. Some approaches seen in the literature include the following:

- Organizations may choose to develop organizational systems capability through processes. One method organizations may choose is to pursue process improvement using an established framework. An example is the Capability Maturity Model® Integration (CMMI) process improvement approach (SEI 2010, 1).
- Concept maps - graphical representations of engineering thought processes - have been shown to be an effective method of transferring knowledge from senior engineering personnel to junior engineering personnel (Kramer 2007, 26-29; Kramer 2005). These maps may provide a mechanism for increasing knowledge of the systems engineering population of an organization.
- An organization may also choose to develop organizational systems competencies by standardizing systems policies and procedures. An example from NASA is their *NASA Systems Engineering Processes and Requirements* (NASA 2007).
- Some organizations use a web portal to store and organize applicable systems engineering knowledge and processes, which assists in developing organizational systems competency. An example is the Mission Assurance Portal for the Aerospace Corporation (Roberts et al. 2007, 10-13).
- Another approach being considered in the community is the development of a rotating professor role, where the person would work at the company and then at a university to strengthen the link between academia and industry.
- Another approach is to alter organizational design to foster and mature a desired competency. For example, an organization that identifies competency in the area of reliability as critical to its SE success may develop a reliability group, which will help foster growth and improvement in reliability competencies.

Organizational Certification

Certification at the organizational level also exists and can be a means for ensuring competency. ISO certification is one example (ISO 2010). Before taking this approach, the organization should verify that the capabilities required by the certification are indeed the systems capabilities it seeks. For more on determining appropriate organizational capabilities, see Deciding on Desired Systems Engineering Capabilities within Businesses and Enterprises.

Repositioning the Product Life Cycle

An organization may also choose to reposition its product life cycle philosophy to maintain system competency. For example, NASA has done this with its APPEL program (APPEL 2009).

Since the systems competencies of individuals are primarily developed through experiential learning, providing experiential learning opportunities is critical. Shortening the product life cycle is one way to ensure that individuals acquire the full range of desired competency sooner.

Maintaining Competency Plans

An organization that has developed an SE competency plan should consider how to maintain it. How, and how often, will the competency plan be re-examined and updated? The maintenance process should account for the ongoing evolution of global contexts, business strategies, and the SEBoK. The process for assessing competencies and taking action to improve them must be part of the normal operations of the organization and should occur periodically.

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Additional References

None.

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