The Context and Why of Competence

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Abstract. Competence with respect to systems engineering is a topical debate and research area. At the same time, there is a debate in human resource management on the exact definition of competence. It is imputed that a constructivist approach to defining the construct 'competence' may be of benefit to the work relating to competence and systems engineering in that it will assist in considering viable definitions of competence. The primary focus of this paper is on individual competence in the systems engineering discipline. The possible purpose of use of the construct competence and the various areas of use will be considered. In order to focus on the purpose and potential use of defining competence at an individual level, various factors of the specific context that influence this description are discussed. The paper proposes a framework for use in a constructivist approach to describe systems engineering competence.

Introduction

The construct 'competence of systems engineers' is heavily debated, discussed and researched. In the proceedings of the Nineteenth Annual International Symposium of INCOSE (International Council on Systems Engineering) as well as in the Proceedings of the Third Asia-Pacific Conference of APCOSE,(Acian-Pacific Council on Systems Engineering) several authors refer to it (Brown 2009, Convalves and Britz 2009, Cook 2009, De Souza and Langford 2009, Genosh 2009, Kasser, Hitchins and Huynh 2009, Kumar 2009, Kupeski 2009, Pyster 2009, and Snoderly 2009). Moreover, the actual definition of 'competence', and its theoretical framework, is itself heavily debated in Human Resource Management literature (Boon and Van der Klink 2002, Pellissier 2009 and Stoof, Martens, Van Merriënboer and Bastiaens 2002). In fact, the terms 'competence' and 'competency' are used interchangeably. Although it appears to be attractive to have a single definition for competence (Pellissier 2009) one must ask whether it is really necessary. A constructivist approach where it is accepted that many potentially useful definitions exist may be more appropriate (Stoof *et al*. 2002). A viable definition for a specific use can be of benefit when competence of systems engineers is considered.

There are many reasons for the differences in definition, but two main reasons are linked to the major pedagogical theories, such as behaviourist and cognitive, on how people learn and the differences in national educational policies (Boon and Van der Klink 2002). The American and typical European approaches differ in the purpose of use, scope and procedure. The American approach can be seen as a focus on outputs and the European approach as a focus on inputs. The European approach is demonstrated in the British approach where competencies are viewed as standards for professions as well as in the German approach where competence is linked to official certification or qualification (Boon and Van der Klink 2002). In the American approach, the behaviour of excellent performers is the source of development of competence lists and this is used to focus on the development of competence in individuals and organisations (Boon and Van der Klink 2002).

Organisations are focussed on achieving improved performance and competence is seen to have a causal relationship to performance (Garavan and McGuire 2001, Aston 2008). Understanding the construct and theoretical framework of competence can therefore have many potential uses. To be usable and useful, it will be necessary to develop grounded technological rules that can be used to describe the competence needed in a specific role or context. In this paper a constructivist view of competence is given that provides the framework in which competence for systems engineers in a specific context or role can be described. The intent is not to focus on application or detail, but rather to identify areas of further research and to provide a framework as a basis for such research.

Dimensions in Defining Competence

The concept of a single best way to do a task is based in the work of Taylor (1911), which deals with the act of searching for a single set of competence characteristics for a situation. There are many definitions for competence, based on the pedagogical and other approaches of the various authors. Many of these definitions attempt to define the ideal mixture of skills, knowledge, and attitude and experience that enables people to deliver high level performance that may add value to an organisation (Garavan and McGuire 2001).

Stoof *et al.* propose that there are five dimensions that determine which definition of competence may be viable in a specific context (2002):

Personal vs. task characteristics

Individual vs. distributed competence

Specific vs. general competence

Levels of competence vs. competence as a level

Teachable vs. non-teachable competence

Constructing a definition for competence that is viable for a particular situation depends on the choices made in each of the above dimensions. Assumptions that are held by stakeholders in the process of defining competence will become visible when these choices are made. The specific use that the definition of competence is aimed at determines many of these choices

Potential Uses of Competence

The purpose or function of defining competence can be perceived from three perspectives (Boon and Van der Klink 2002). They are competence as individual characteristics, competence as characteristics of an organisation, and competence as a tool to structure discourse between practice and education.

Competence as a set of individual characteristics is based on the causal relationship that is assumed between these characteristics and performance. However, this set of characteristics, or part thereof, may not directly translate into measurable outcomes of performance judged against goals and objectives (Aston 2008). The characteristics that are considered include skills, knowledge (how to and what, as well as explicit and tacit) attitudes and experience. The combination of the characteristics and especially the balance between task- and people-oriented competence is the source of much research as there is an assumption that a superior set of competence characteristics will lead to superior performance. In order to utilise the competence construct it is important to identify indicators and measures that will enable the assessor to identify competence, and to distinguish between levels of competence. The choices made in the dimension of specific vs. general competence will be highly dependent on the specific intent. Where the perspective of the organisation is on finding an "ideal candidate", the perspective of the individual is on achieving competences that lead to career advancement and that can also articulate between jobs. Individual competence can be used for many purposes including selection, training needs assessment, performance appraisal, career development and certification.

Competence as a characteristic of the organisation is attributed to the work of Prahalad and Hamel (1990) that linked the competitiveness of organisations to the resources of the organisation. The terms 'capability' and 'competence' were used interchangeably by Prahalad and Hamel (1990), but Javidan refers to capability as a functionally based view and competence as a cross-functional integration and coordination of capabilities (Javidan 1998). These concepts are linked to the ability of an organisation to exploit resources, including its human resources and processes. Identifying organisational competence can be used in evaluation to understand how to potentially benefit from it in setting strategy (Javidan 1998). It can also be used by organisations to identify improvement or learning opportunities in assessment or auditing, or in accreditation activities. The dimension of distributed competence vs. individual competence is highly relevant as organisational competence does not imply that all functional competence must be equally distributed. Two aspects become prominent: the organisational systems and processes needed in systems engineering and the appropriate competence of the team of systems engineers in the organisation should both be considered when organisational competence or capability is considered.

Competence as a discourse between practice and education is a perspective that considers how changes in the requirements of practice can be translated into educational requirements. It supports the change of education from the traditional pedagogical context to moving towards a competency approach (Boon and Van der Klink 2002, Garavan and McGuire 2001). From this perspective the differentiation between teachable and non-teachable characteristics of competence is obviously very important. However, the identification of other characteristics that may predict success in education or careers is also important as they could form the basis of selection or career choice.

Valid and accepted standards exist for the definition of competence at an organisational level in systems engineering. These include the ISO/IEC 26702 standard that defines the tasks that are required in the systems engineering process from a project perspective and the EIA731.2 that defines the appraisal method for the Systems Engineering Capability Model. However, the concepts of individual competence and the discourse between education and practice still require attention. INCOSE has clearly stated in its Vision 2020 (2007) that there are specific areas that require focus over the next few years, and these include the processes of systems engineering and understanding the nature of systems as well as systems engineering education. The call for papers for the Twentieth International Symposium of INCOSE (2009) also clearly indicates a focus on defining competence for systems engineering as well as the discourse between practice and education.

Specific Challenges in Considering Individual Competence

The assumed **causal relationship between competence and performance** is at the basis of individual competence definitions and descriptions. Performance is however a function of a number of variables of which competence is only one. In fact, the actual relationship as well as the other variables involved depends on whether competence is viewed from a behavioural, cognitive or constructivist approach. In this section some topics that are particularly pertinent when considering individual competence in systems engineering are discussed.

A single ideal, positivist description of individual competence would be **context free.** This will make it possible to define a prescriptive list of competence characteristics for all possible purposes (Garavan and McGuire 2002). However, this is not possible and therefore the stated, or unstated, aim of standardised descriptions is to give prescriptive guidance for a generic part of the competence characteristics. The challenge to understanding and interpreting any identified competence characteristics is to clearly identify the context in which they were developed as well as the purpose for which this was done. The complex interaction between an individual and an organisation will impact on how competence is translated into performance as well as the competence characteristics required.

The **culture** of an organisation in which systems engineers work will have a very definite influence on the competence characteristics that are required to perform well (Collins and Callahan 2009). It is important to understand how this culture affects the roles systems engineers have to fulfil in various organisations (Collins and Callahan 2009).The culture of an organisation can also affect a systems engineer in many ways, including specific personality characteristics or the way in which competence translates into performance.

Domain-knowledge / industry-specific knowledge is extremely important for systems engineers to perform well. The possible industries and applications in which systems engineering can be applied make it difficult to identify and specify the specific competence descriptions fully. In some cases this competence description is listed as ‘engineering’ (Kasser, Hitchins and Huynh 2009) or it is left out of the construct (INCOSE UK 2006). Tailoring for a domain may be necessary for many of the potential uses. The domain can be industry-specific, but even in what is predominantly a military context there can be significant differences in the combination of competence characteristics (Cook 2009).

The **roles that systems engineers fulfil** in organisations have changed during the last 50 years and

the role or roles may be different in every organisation where systems engineering is utilised (Kasser, Hitchens and Huynh 2009). In 1996 Sheard identified 12 such roles with the last one basically defined as 'other', based on practice needs as expressed in job advertisements. In 2009 Kasser *et al.* categorised the activities in which systems engineers engage into four sets: systems engineering, engineering, management and other.

It is also important to understand at which **systems level** within a systems hierarchy systems engineering is practised. At a very simplistic level, significantly different competence characteristics are needed at a 'system of systems' level than at the more traditional levels that systems engineers function. There could be subtle differences at other hierarchical levels as may be applicable in specific industries. Kasser *et al.* use the term 'types' of systems engineers to deal with this aspect (Kasser, Hitchens and Huynh 2009). They propose that a form of competence and potential assessment be used early in a systems engineer's career to identify at what level an individual may be able to function.

The use of individual competence characterisation for **selection** can be applied at many different stages of a systems engineer's career. The use of competences for selection implies that a model for prediction of success exists and has been carefully considered. This may not be as straightforward as it appears, as a 'highly competent' systems engineer in one role may not be competent in another role. Where selection is based on competence characteristics, it is therefore extremely important to consider the context in which the systems engineer is expected to perform. Where selection criteria are used to discriminate between individuals for career development or further education the criteria must be based on due consideration.

There are a number of purposes for **accreditation or certification** of systems engineers. One ofis the level at which an individual can sign to declare due diligence on a design. This due diligence can then be interpreted as acceptance of liability at a personal, professional level as well as acceptance on behalf of an organisation. This is potentially a very sensitive issue as it may also affect an individual's professional status in a specific engineering discipline. In specific countries where legislation allows for it, individuals can in fact be held criminally liable should injury or death occur in the use of a system that they have signed off on. **Risk management** deserves more attention especially when competence levels for certification or accreditation are set.

The term 'experience**'** features in most definitions of competence. In most cases **experience** refers to a specific set of competence characteristics that an individual has and that can be transferred to performance. Correlation between years of experience and effectiveness is even drawn in some cases (De Souza and Langford 2009). In other cases minimum years of experience is set as 'required' before progression between different levels of systems engineering certification (INCOSE. 2009). What is not addressed here is the question 'what experience?' Not all experience is equal and individuals can spend years gaining repetitive experience that does not translate into an advance in their competence characteristics at all. Workplace learning as well as career development requires careful thought to recommend experience trajectories. Experience without reflection may also not lead to improved performance and structures, and mechanisms to encourage structured reflection should be accessible to systems engineers who wish to develop their competence characteristics. The effect of involvement in a successful project and a less than successful project can also have significant differences in developed competence characteristics. Finally, it is important to note the benefit to performance of obtaining vicarious experience through observing performance by a competent systems engineer in developing competence.

The link between the performance of an individual and the competence of the organisation in which the individual works is important. Teamwork is essential in systems engineering and as in any system the team competence is more than the sum of the individual competence characteristics in a **team** (Stoof *et al.* 2002). The mix of individual competence characteristics that team members should have to ensure optimal performance at a team level needs focus as well. The link between organisational competence and individual performance includes the impact that **maturity of systems and processes** will have on the performance of a systems engineer (Garavan and McGuire 2002)

If a cognitive approach is used instead of the more traditional behaviourist approach when the link between competence and performance is considered, the aspect of self-belief or **self-efficacy** must also be considered. This includes the use self-regulatory mechanisms and reflection. Performance may be predicted by an individual's self-belief if that individual has the minimum competence characteristics. It must of course be mentioned that no amount of self-belief can compensate for inadequate skills and knowledge (Pajares 2002).

Sources of Identifying Individual Competence

There are several sources that can be used to identify the detail of various competence characteristics. When the sources to be used are identified, the actual use of the construct must be kept in mind as there may be an **inherent bias** in some of the sources. Identification of competence characteristics is often linked to larger processes, such as human resource development or curriculum development. The stakeholders in a specific endeavour will also influence the sources to be used, but where stakeholders are directly represented, potential bias should be addressed on a continuous basis. This bias can be based in the specific domain or context that the stakeholders come from or derive from fundamental or even unconscious assumptions that the stakeholders may have regarding learning or performance. It can also be due to the justification of the stakeholders' own claim to competence. The sources could be: validated, context-specific or systems engineering specific (such as job function analysis).

Task descriptions are a fundamental source in identifying competence characteristics. Task identification can be done from a valid source such as standards (ISO/IEC 26702 2007). However, where many tasks are required it will be necessary to group the tasks together and the consistency of such groupings on various occasions will need to be addressed. This is similar to job function analysis but has the weakness that is unable to identify the softer aspects of competence characteristics such as behaviour, attitude, intuition and creativity (Garavan and McGuire 2002).

Observations, formal or informal, could also be a useful source of identifying competence characteristics. In this case it will be much easier to determine the softer characteristics, including interpersonal behaviour. Should observation be used, the process must be well structured, scientifically sound, and designed to enable valid and reliable conclusions to be drawn.

Self-evaluation of practitioners is another source that is often used. When self-evaluation is used there may be inherent bias in the assessments, due, amongst other things, to the context in which practitioners may be experienced. Practitioners may also regard certain competence characteristics as tacit and may not be able to identify those.

An **expert panel** can be used to solicit competence from either recognised expert performers or

representatives of industries where such competence occurs. The challenges are similar to those of self-assessment with the potential for bias based on the context from which the panel comes.

Individual competence characteristics may also be determined by **translating from organisational competence.** There are valid and agreed competence descriptors for organisations on the level of a systems engineering project (ISO/IEC 26702 2007) and at the level of a company with a systems engineering capability (EIA 731.2 2002). These can be used to determine what the distributed competence characteristics of a systems engineering function should be. The effect of the relationship between the other resources of organisational competence must be kept in mind.

Adding context-specific competence characteristics to generic characteristic is a fast and focussed way to develop context-valid competence characteristics. The Systems Engineering Competencies Framework (INCOSE UK 2006) is an excellent start to this process. However, the actual process to determine the context-specific competence characteristics will need to use sources as identified here.

Practice requirement is an important source, both for identifying competence requirements for individuals and for defining competence characteristics that can be used as discourse with education. This can be done through panel representation such as an advisory board (INCOSE UK 2006) or through analysis of advertisements (Sheard 1996, De Souza and Langford 2009)

In a case study where the context-specific competence characteristics for general practitioners were determined (Patterson *et al.* 2000) various sources were used and triangulated to compensate for the specific weaknesses that may be inherent to a source. It is important that the role of a general practitioner as opposed to a medical practitioner was taken into account. Critical incident analysis was done by practitioners in a focus group, as well as by their patients, and these two sources elicited some differences in the identified competence characteristics. As a third source for triangulation, behavioural observations were done and coded. A combination of these three sources provided a valid description.

Where context-specific competence characteristics for systems engineers are determined, various sources will be needed to provide valid descriptions.

Discussion

It is evident that creating a single competence description for systems engineers may not be the best route or even achievable. There are various forms of competence that are currently defined and internationally accepted. The **competence/capability definition at organisation level** exists and has been validated (ISO/IEC 26702 2007, EIA 731.2 2002). The different definitions may need to be adapted to allow for competencies that could be identified as additional at the ‘system of systems’ level as well as for other possible competencies or capabilities that may be required as systems engineering continues to mature.

Competence as a discourse between practice and education underlies the INCOSE certification system as well as the current work by INCOSE UKAB. It appears that the constructs for competence that are used in these two cases are mostly those of teachable competencies, with a few behavioural skills identified in the work of INCOSE UKAB. It is also evident from the INCOSE 2010 Vision (INCOSE 2007) that this is seen as an area that requires focus over the next decade.

The Systems Engineering Competencies Framework (INCOSE UK. 2006) describes identified **individual competence** characteristics that are seen as generic in a fairly wide industry setting and implies that organisations should be able to tailor certain context characteristics identified as 'domain knowledge'. It may be useful to develop grounded rules or other prescriptive guidelines on how to develop valid competence characteristics within a specific context. This context may include the specific role that a systems engineer is expected to fulfil.

The role of **experience** as a part of the competence characteristics of a systems engineer is important and the development of ideal experience paths as a career development tool may be helpful. It is important to consider the breadth of experience and not only the length of potentially repetitious experience. In addition to this, the effect of **reflection** to ensure that experience translates into competence characteristics should be recognised and such processes facilitated. There is scope for contributions to the profession in this respect.

Teachable and non-teachable competence characteristics should be distinguished in various selection processes during the career of a systems engineer. These may be drivers in the selection of systems engineering roles that an individual could assume as opposed to determinants for a level of competence.

The link between **accreditation or certification and potential liability** should be considered and, if needed, the relevant competence characteristics that may be needed should be identified. These may then need to be articulated in the process of certification or accreditation.

In Figure 1, a framework for a constructivist approach to describe systems engineering competence is presented.

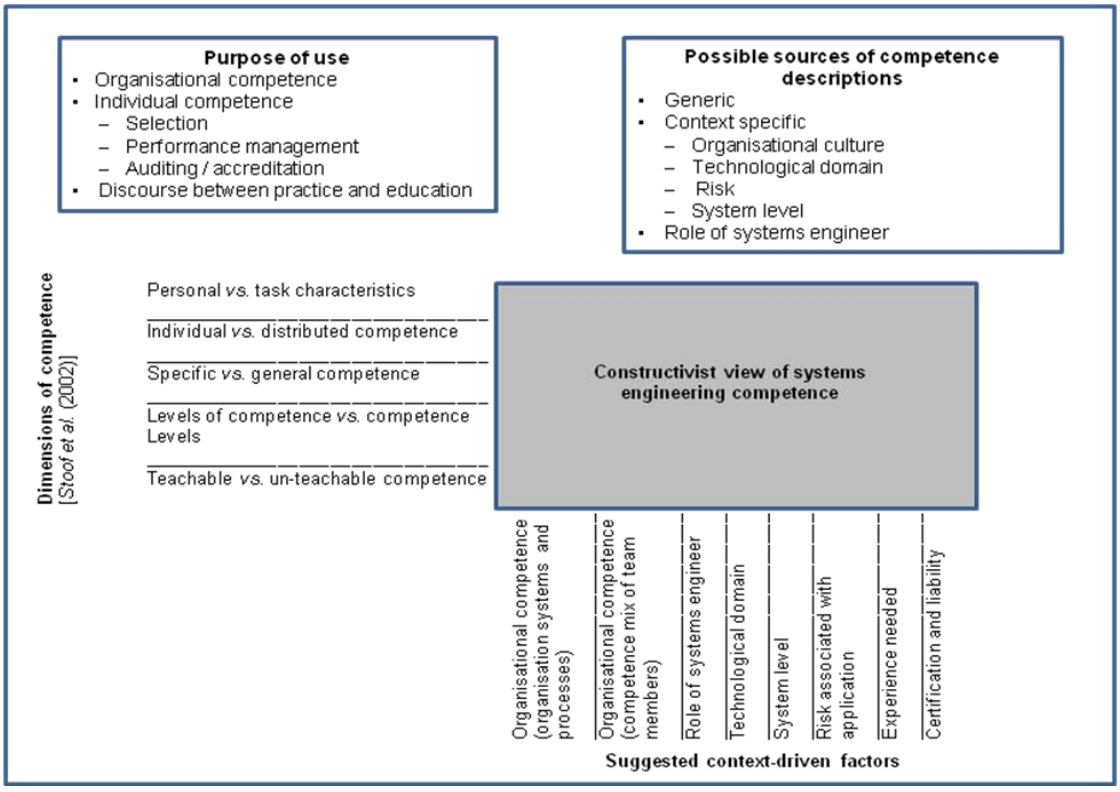

Figure 1: Proposed framework for a constructivist approach to describe systems engineering competence

In this framework it is indicated that the purpose of use and the possible sources of competence descriptions need to be determined as part of the description of competence characteristics. . The constructivist approach to describe viable competence characteristics will then require that the dimensions of competence (Stoof *et al*. 2002) be used in a matrix with the different factors that can be used to describe the context in which the systems engineering will be done. This framework can be used as an initial construct in research designed to investigate this important area further

Conclusion

The search for grounded technological rules that will guide the specification of systems engineering competence for a specific context and role has only just started. Whether the search for competence of systems engineering is focussed on setting standards for the profession or on development to enhance performance, it is important to note that frameworks for generic and specific competence characteristics will evolve. The process of determining competence characteristics will therefore be never-ending and the processes and methodologies for updating such characteristics are important. What will be useful is to have grounded rules that will guide the development of a competence description for a specific role of a systems engineer in a specific context. The search for this description will continue.

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BIOGRAPHY

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David Blyth is the Chief of Electronic Engineering of the SAAF. He has directed diverse engineering projects, developed and improved engineering processes and mentored personnel. He is currently seconded to the engineering directorate of the Logistics division where he participates in the development of strategy and policy. He started his career with the South African Navy in a radio/radar technical mustering. He left to study towards an engineering degree after which he developed microwave products, and participated in and managed inertial navigation projects. He holds a B Eng (Electronics) and an MBA degree from the University of Pretoria. He is registered as a professional engineer (PR Eng) with the Engineering Council of South Africa and is a member of INCOSE.