Competency Area 1: Foundational Knowledge

The Foundational Knowledge competency area outlines the basic process definition and the knowledge and skills in statistical methods which constitute the conceptual foundation on which the PSP is built. The major knowledge areas composing the Foundational Knowledge competency area are as follows.

1.1 Process Definition – This knowledge area outlines the fundamental concepts and skills that enable engineering professionals to create, use, and stabilize the defined processes of which PSP is comprised.

1.2 Process Elements – This knowledge area delineates the components that are included in any personal process and form a framework for organizing project work.

1.3 Measurement Principles – This knowledge area describes process and product measurement and explains why measures are essential for producing high-quality work.

1.4 Statistical Elements – This knowledge area discusses the statistics which provide a foundation for planning and tracking methodologies used in the PSP, and that also provide an objective means of analyzing and improving personal processes.

References: The material covered in this competency is detailed in the following works.
[Humphrey 95, Chapters 1, 7, 11, 13, Appendix C]
[Humphrey 05a, Chapters 1, 2, 6, 8, 13]

Knowledge Area 1.1: Process Definition

The PSP is a series of defined processes that allow engineering professionals (such as software developers) to produce high-quality products on time and within budget. This knowledge area outlines the concepts and skills needed to create, stabilize, and use defined processes.

1.1.1 Process

A *process* describes the sequence of steps that a knowledgeable professional should follow to do a specified task.

1.1.2 Defined process

A *defined process* is a documented sequence of steps required to do a specific job. Processes are usually defined for jobs that are done repeatedly and need to be done in the same way each time that they are performed.

1.1.3 Benefits of defining a process

A defined process provides

- a clearly delineated framework for planning, tracking, and managing work
- a guide for doing the work correctly and completely, with the steps in the proper order
- an objective basis for measuring the work and tracking progress against goals, and for refining the process in future iterations
- a tool for planning and managing the quality of products produced
- agreed-upon, mutually-understood procedures for team members to use in coordinating their work to produce a common product
- a mechanism that enables team members to support each other throughout the course of the project

1.1.4 Process documentation

Process documentation is the act of producing a succinct written representation of a process, its entry and exit criteria, the process phases, and the process steps for each phase. The process documentation should not contain tutorial or other explanatory material typically needed by unskilled or uninformed individuals; it should provide only the necessary information that experienced practitioners require to enact the process steps.

1.1.5 Processes and plans

Whereas processes are defined sets of steps for doing a task or project, *plans* include both the process steps and other elements required for a specific instantiation of that process, such as resources needed, roles of various project members, schedules, budget, goals and objectives, commitments, and identified risks.

1.1.6 Personal processes

A *personal process* is a defined set of steps or activities that guide individuals in doing their personal work. It is usually based on personal experience and may be developed entirely "from scratch" or may be based on another established process and modified according to personal experience. A personal process provides individuals with a framework for improving their work and for consistently doing high-quality work.

1.1.7 Enactable and operational processes

An *enactable process* defines precisely *how to do* a process, and includes all of the elements required for using the process. An enactable process consists of a process definition, required process inputs, and assigned agents, resources (e.g., people, hardware, time, money), and exit criteria. An *operational process* defines precisely *what to do* by listing the required tasks in enough detail to guide a knowledgeable professional through doing that task. Operational processes provide sufficiently detailed guidance so that teams and individuals can make detailed plans for doing a project and then use the process to guide and track their work. The PSP is an example of an enactable operational process.

1.1.8 Process phases

A defined process consists of a set of steps, elements, or activities that are generally called *phases*. Simple process phases consist of steps with no further substructure. More complex processes may have phases that are themselves processes. The steps or activities in each phase are defined by a *script* (see 1.2.2). At a minimum, any process must have three phases: planning, development, and postmortem.

1.1.9 The PSP process phases

The basic PSP process has three phases.

1. **Planning**: Produce a plan to do the work.
2. **Development**: Perform the work.
   a. Define the requirements (see 4.2.2)
   b. Design the program
   c. Review the design and fix all defects
   d. Code the program
   e. Review the code and fix all defects
   f. Build or compile and fix all defects
   g. Test the program and fix all defects
3. **Postmortem**: Compare actual performance against the plan, record process data, produce a summary report, and document all ideas for process improvement.

1.1.10 Incremental development

The PSP facilitates incremental development. For larger projects, each increment can be an entire PSP project, a PSP development phase, or part of a PSP development phase, depending on the individual's needs.

- Various predefined PSP incremental development processes are available [Humphrey 05a].
- The PSP methods are used most effectively with large-scale incremental development when each increment is of high quality.

1.1.11 Process tailoring

Process tailoring is the act of customizing a process definition to support the enactment of that process for a particular purpose (see 7.1).

1.1.12 Process building and refining

Skilled PSP practitioners can use or tailor the PSP scripts to define or customize their own high-quality personal processes for building a product. Professionals should define their own processes to ensure that the processes fit their needs as closely as possible [Humphrey 95, p. 16]. As the process is enacted on various projects, the users of the process should strive for continuous refinement and improvement in both the process itself and in the quality of the products produced using that process.

Knowledge Area 1.2: Process Elements

This knowledge area describes the components that are included in any personal process and form a framework for organizing project work.

1.2.1 Process elements

Process elements are components of a process. The PSP contains four basic elements: scripts, forms, measures, and standards.

1.2.2 Scripts

Scripts are expert-level descriptions that guide personal enactment of a process. They contain references to pertinent forms, standards, checklists, sub-scripts, and measures. Scripts may be defined at a high level for an entire process or at a more detailed level for a particular process phase. A process script documents

- the process purpose or objective
- entry criteria
- any general guidelines, usage considerations, or constraints
- phases or steps to be performed
- process measures and quality criteria
- exit conditions (such as defined work products or required process data)

1.2.3 Forms

Forms provide a convenient and consistent framework for gathering and retaining data. Forms specify the data required and where to record them. As appropriate, forms also define needed calculations and data definition. Paper forms may be used if automated tools for data gathering and recording are not readily available.

In PSP, *checklists* are specialized forms used to guide personal reviews. Each checklist item verifies an aspect of the product's correctness or conformance with standards or specifications. The checklist items include the most frequently occurring defects that can be found with a review. The entire product is reviewed with a focus on only one checklist item at a time. As the review for each item is done, that item is marked complete. When the entire checklist has been completed, it serves as a record of the review.

1.2.4 Measures

Measures quantify the process and the product. They provide insight into how the process is working by enabling users to

- develop data profiles of previous projects that can be used for planning and process improvement
- analyze a process to determine how to improve it
- determine the effectiveness of process modifications
- monitor the execution of their process and make next-step decisions
- monitor ability to meet commitments and take corrective actions as needed

1.2.5 Standards

Standards provide precise and consistent definitions that guide the work and the gathering and use of data. Standards (such as coding, counting, and defect standards) enable measures to be applied uniformly across multiple projects and to be used consistently. PSP practitioners should be able to recognize areas where standards would be useful and create them when needed.

Knowledge Area 1.3: Measurement Principles

This knowledge area describes process and product measurement and explains why measures are essential for producing high-quality work.

1.3.1 The need for measures

Measures are used in the PSP so that process changes can be identified, assessed, logically implemented, and judged as effective or ineffective.

1.3.2 Measurement types

To be useful for process management, all measures should be defined, precise, accurate, and significant. There are two main types of measures used in PSP: artifact measures and process measures.

- *Artifact measures* are used to quantify product characteristics, such as product size or defects found per element.
- *Process measures* describe or quantify the development or repair process used, and are classified either as historical or current measures.
  - *Historical process measures* are used after the process has been performed to record actual data such as inspection time, test time, and so on.
  - *Current process measures* are used while the process work is being performed to record data such as duration of inspection meetings, code review time as a percentage of coding time, and the like.

Both artifact and process measures may be based on single or multiple measurements. The choice of single or multiple measures depends on the nature of the data and the use for that measure. When multiple measures are taken, a statistically sound procedure is needed to calculate the values to be used from these measures.

1.3.3 Defined measures

A *defined measure* is one that has an explicit and unambiguous meaning. For process measures, this requires the process to be precisely defined to include entry and exit criteria for every phase. The properties to be measured in the process must also be completely and explicitly defined.

1.3.4 Precise and accurate measures

A *precise measure* is one that specifies a value to a suitable level of precision, as with a specific number of digits after the decimal point. An *accurate measure* is one that correctly measures the property being measured. Measures can be precise and accurate, precise but inaccurate, imprecise but accurate, or both imprecise and inaccurate. For process management purposes, measures should be as precise and accurate as possible.

1.3.5 Meaningful measures

To be meaningful, measures must actually represent the true value of the process or product property being measured, thus indicating that the measurement represents an objective characteristic of a real phenomenon. The measurement's significance increases with the number and consistency of the measurements that are taken.

1.3.6 Uses of process measures

Process measures can be used to evaluate product or process characteristics, to estimate product or process elements, or to predict future outcomes. They can also be used as the basis for determining improvement opportunities and their likely individual and business objectives.

Knowledge Area 1.4: Statistical Elements

Statistics are the foundation for PSP planning and tracking methodologies and also provide an objective means of analyzing and improving personal processes. (Note: PSP-specific definitions, interpretations, or application of statistical terms or elements are called out in each applicable knowledge area subsection.)

1.4.1 Distributions

A *distribution* is a set of numerical values that are generated by some common process (actual sizes of parts developed or size estimates).

1.4.2 Mean

The *mean* is the arithmetic average value of a distribution. In the PSP, the mean is typically an estimate of the mean of the distribution, not the actual mean.

1.4.3 Variance

Variance is a measure of the spread or tightness of a distribution around the mean. In the PSP, the variance is typically an estimate of the variance of the distribution, rather than the actual variance.

1.4.4 Standard deviation

Standard deviation is the square root of the variance. It is often used to characterize the expected range of deviation between an estimate and an actual value. For example, one method in PSP uses standard deviation to categorize software size into relative size tables. Standard deviation is also used as part of the calculation of prediction intervals.

1.4.5 Correlation

Correlation is a measure of the degree to which two sets of data are related. In the PSP, correlation is measured between estimated and actual size and between estimated size and actual effort.

1.4.6 Significance of a correlation

Significance measures the probability that two data sets have a high degree of correlation by chance. Estimates of size and effort in the PSP are more reliable when based on historical data that have a high degree of correlation that is significant.

1.4.7 Linear regression

Linear regression determines the line through the data that minimizes the variance of the data about that line. For example, when size and effort are linearly related, linear regression can be used to obtain effort estimates from size estimates.

1.4.8 Prediction interval

The *prediction interval* provides the range around an estimate made with linear regression within which the actual value will fall with a certain probability. For example, in PSP, the 70% prediction interval for an estimate of size or time implies a 0.7 probability that the actual value of size or time will be within the range defined by the prediction interval.

1.4.9 Multiple regression

Multiple regression is used in the PSP when estimations of size or time depend upon more than one variable. For example, if modifications to programs require much more time than additions, then "added" and "modified" can be separated into two variables for the regression calculation.

1.4.10 Standard normal distribution

The *standard normal distribution* is a normal distribution translated to have a mean of zero and standard deviation of one. The standard normal distribution is used in the PSP when constructing a size estimating table.

1.4.11 Log-normal distribution

Many statistical operations assume that data values are normally distributed, but some PSP measures do not meet this requirement. For example, size values cannot be negative but can have small values that are close to zero. These distributions also typically have higher probability at large values than a normal distribution. When a log transformation is applied to data sets of this type, the resulting distribution may be normally distributed and, therefore, suitable for statistical analyses that assume normally distributed data. Statistical parameters for the normal distribution may be calculated and then transformed back to the original distribution. Size data in the PSP are generally log-normally distributed, so they must be transformed into a normal distribution for construction of a size estimating table.

1.4.12 Degrees of freedom

Degrees of freedom (df) measures the number of data points (n), as compared to the number of parameters (p) that are used to represent them. In linear regression, two parameters (β_0 and β_1) describe the line used to approximate the data. Since at least two points are needed to determine a line, the number of degrees of freedom is *n-2*. In general, the number of degrees of freedom is *n-p*.

1.4.13 The t-distribution

The *t-distribution* enables estimation of the variance of a normal distribution when the true parameters are not known, thus enabling calculation of statistical parameters based upon estimates from sample data. Like the normal distribution, it is bell-shaped, but it varies depending upon the number of points in the sample. For fewer data points, the distribution is short with fat tails. As the number of data points increases, the distribution becomes taller with smaller tails and approaches the normal distribution. In PSP, the t-distribution is important because it helps to determine the significance of a correlation and the prediction interval for regression, each of which is dependent upon the number of points in the sample data set.