

## Towards a learning process maturity model

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### Abstract

*This paper describes the preliminary work aimed to develop a model for learning process maturity based on the concepts and ideas of the Capability Maturity Model<sup>®</sup>. In developing the learning process maturity model, the principles behind the Capability Maturity Model<sup>®</sup> are explored and a mapping to a learning process maturity model is developed. The model is to be used within the normal teaching cycle as a tool to improving the approach to learning being utilised by learners.*

### Keywords

Capability maturity, learning process

### INTRODUCTION

The Capability Maturity Model<sup>®</sup> is a tool for assessing the extent to which an organisation has established the processes to repeatedly develop high quality software to the customer's requirements on budget and on time (Chrissis et al., 2003). Using the model, an organisation is assessed and a path for improvement can be developed. After achieving the highest level assessment of the model, the organisation will have in place the ongoing tools for self-assessment and improvement.

The Capability Maturity Model<sup>®</sup> (CMM) defines levels of maturity and a set of processes that should be in place if an organisation has developed its full potential for software development. Can the concepts of the CMM be transferred to the learning context? Is there a way of applying the principles that will enable the learner to identify the issues that they need to deal with in order to improve their learning?

The model developed in this paper is a first step in the process to developing a learning process maturity model that can be applied continuously in a learning context and to help the learner identify weaknesses and strengths in their approach to learning and the selection of learning strategies.

### WHAT IS A LEARNING PROCESS?

A process is defined in the Concise Oxford Dictionary (Allen R E, 1990) as

1. a course of action or proceeding, especially a series of stages in manufacture or some other operation
2. the progress or course of something (*in process of construction*)
3. a natural or involuntary operation or series of changes (*the process of growing old*)

A learner can be in the process of learning the subject matter (definition 2). Using process in that context does not clarify what the learner is doing or how they are doing it. They are simply in the process.

The process of learning could also be considered a natural operation or series of changes (definition 3) as we might expect to see in a young child as they develop and explore their world. This definition of process is the basis of a number of theories of cognitive development (Piaget 1969, 1970, (Flavell, 1977; Perry Jr, 1968) and is relevant when assessing the maturity of the learner with respect to cognitive and metacognitive development.

This concept of process does apply to the software developer as the developer moves from being a novice to being an expert. A novice software developer has a focus on detail while an expert will recognise and utilise patterns (Pennington, 1987; Soloway et al. 1988). Novices seek example solutions while experts rely on developing solutions from concepts. Novices seek to apply design patterns and processes by rule while experts see design patterns and processes as guidelines. There is a distinction between the person who struggles to learn programming (ineffective novice) and the person who can successfully learn to program (effective novice) with respect to the strategies that they utilise (Robins et al. 2003). The journey from ineffective novice to effective novice, and from effective novice to expert reflects the changing of perspectives in terms of what is being learnt and in the task being performed (Kegan, 2000; Mezirow, 1991; Mezirow, 2000).

It is in the context of a “series of stages” (definition 1) that is used in the CMM and that gives us a way of being able to evaluate what a learner is doing or of being able to assist the learner to modify their approach to learning. Although not explicitly stated in all texts, this is the assumption that underlines the work of some authors (Harri-Augstein and Thomas, 1991; Senge et al., 1994) when they describe steps that a learner can use.

In the field of software development, the OPEN process framework says, “The overall process itself consists of a number of Activities. Activities are granular descriptors of a collection of heterogeneous jobs that need to be done. These can be decomposed into a number of tasks, each of which is readily ascertained as being either complete or in progress (i.e. incomplete). However, since Tasks have to be done by someone (or some thing such as another piece of software), it is useful to introduce a metaclass called Task performance, which consists of a Task and its producer.” (Henderson-Sellers and Unhelkar, 2000:9-11).

A process and the activities of a process are not aimless. They are intended to produce a tangible result (a work product or an artefact). In order to perform the activity and to produce the work product, a producer performs a task utilising a technique. Dependencies between tasks are defined by their assertions (pre-conditions (what is required for the task to start) and the post-conditions (what the task has produced)). The workflow represents the sequence of tasks performed.

The process followed is not the same for all projects. It will be tailored to the requirements of the project by selecting appropriate activities and tasks. As well, “Processes may be in an individual’s head or may be written down as an organizational (or international) standard to be followed on each project. They may be large or small, ‘authoritarian’ or flexible” (Henderson-Sellers and Unhelkar, 2000:4).

Based on this perspective of process, we would expect a learning process to involve a series of activities each aimed at achieving some aspect of the learning (a work product). We would expect that the work product would be assessable. That assessment of the work product should reflect the degree of learning that has occurred but the assessment of the work product does not reflect the effectiveness of the process used to obtain that outcome.

When reflecting on the activities and work products of software development, we see that these include the clarification of objectives (requirements), identification, selection, and development of appropriate solution strategies (analysis and design), determining a method for testing the solution (writing tests), preparing the solution (coding), assessment of the solution (testing), reviewing progress and reassessing further requirements (review and planning the next iteration), and transition to production (implementation). The Open Process Framework (Firesmith and Henderson-Sellers, 2002; Henderson-Sellers and Unhelkar, 2000) defines a high level process model and provides a menu of activities and tasks from which specific processes can be built.

With respect to learning, the activities and work products should also cover determination or clarification of learning requirements (learning outcome determination), identifying ways of obtaining the required learning outcomes (building a series of task representations and selecting learning strategies), defining how to determine whether the learning has been achieved (define the learning outcome criteria), carrying out the learning (using the selected learning strategies), determining whether the learning has been achieved (assessment), identifying further learning needs, and applying learning in a work or non-learning context (application of learning). Like the OPEN process

framework, we would expect that it would be possible to list activities and tasks that could be selected from to build a specific learning process.

## **WHAT IS MATURITY?**

In software development, the maturity of an organisation's capability to develop software may be defined as the organisations ability to "repeatedly and reliably deliver customers requests" (Poppendieck, 2003) or the extent to which an organisation that has established the processes to repeatedly develop high quality software to the customer's requirements on budget and on time. Maturity in this context relates to the organisation and its institutionalization of the processes (Chrissis et al., 2003).

The Concise Oxford Dictionary (Allen R E, 1990) defines mature as

1. with fully developed powers of body and mind, adult
2. complete in natural development, ripe
3. (of thought, intentions, etc.) duly and adequate.

In an educational context, learning maturity may be defined as the extent to which a person has developed their capability to repeatedly and reliably achieve learning outcomes that involve ability to apply, critique, analyse, reflect, and hypothesise on the subject under study. In terms of the dictionary definition, a mature learner will have fully developed powers of learning where powers of learning may be defined as the cognitive and metacognitive skills (Bloom et al., 1956; Brown, 1978; Brown, 1987; Facione, 1990; Flavell, 1979) that characterise deep and critically reflective approaches to learning (Biggs, 1999; Biggs and Collis, 1982; Mezirow, 2000; Schön, 1983). The mature learner accepts changes to their perspective of learning and of the subject matter (Mezirow, 1991) and commits to their current understanding based on sound reasoning (King and Kitchner, 1994; Perry Jr, 1968; Polanyi, 1958) and the processes of the subject area (Costa and Liebmann, 1996).

Identifying whether a learner is using deep, achieving or surface strategies is inadequate to determine learning maturity (Biggs and Collis, 1982; Hunt, 1995) since the selection of a learning strategy relates to the learner's task representation rather than to the characteristic of the learner (Hunt, 1995). Even in a task representation that may involve the characteristics of a deep approach to learning, the learner may initially utilise surface strategies to build a knowledge base before endeavouring to utilise the strategies of deep approaches to learning. There is sequencing in the use of strategies depending on the learner's prior knowledge and the learning task at hand. A mature learner is able to select appropriate strategies based on their prior knowledge and the learning task representation.

Prior knowledge has been identified as a key factor in learning success (Hunt, 1995). Bransford et al. (Bransford et al., 2000) emphasise the need to "draw out and work with the pre-existing understandings that their students bring with them" (p 19). In the context of a process model for learning, we would expect to see that a mature learner's learning process identifying learning strategies that will identify relevant pre-existing understandings and knowledge and for connecting the current learning with these prior understandings and knowledge.

## **THE CAPABILITY MATURITY MODEL**

The capability maturity model has been developed as a tool to assess organisational capability to reliably deliver software of a high quality on time and within budget. It differs from other process standardisation efforts in that it is designed to foster ongoing improvement of those processes. Initial versions of the model (Paulk et al. 1993) were developed based on the best practices and a sequential process model for software development. Over time, the model has adapted but still carries with it some of the assumptions of earlier process structures. A number of different models have been developed focussing on different processes for product delivery. These have now been integrated into the Capability Maturity Model<sup>®</sup> Integration (Chrissis et al., 2003).

The focus in the Capability Maturity Model<sup>®</sup> Integration is the "institutionalisation" of processes within an organisation. Levels are defined for process institutionalisation. These levels are defined from three different perspectives. The first is the general principles for process institutionalisation and apply to process areas. These definitions provide the overriding perspective for the model. The second

is the capability levels for the continuous representation. *Capability* levels “apply to an organisation’s process improvement achievement in individual process areas” (p 75). The definitions for the capability levels closely match the general principles for process institutionalisation. The third is the maturity levels of the staged representation. *Maturity* levels “apply to an organisation’s process improvement achieved across multiple process areas” (p 75). The naming used is consistent in all three definitions of the levels.

The representation models provide two different approaches to improving an organisation’s process capability. The continuous model enables an organisation to focus on improving individual processes. The order of process improvement is not defined. The levels of the continuous representation apply to individual processes. In contrast, the staged process provides direction on which processes need to be developed next. The levels of the staged representation are based on the processes that need to be implemented to achieve that maturity level.

For the purposes of developing a learning maturity model, our primary interest is the principles of these maturity levels. Since the general principles are reflected in the continuous representation, the following summary draws together the definitions from the two representations.

### **Level 0: incomplete (continuous representation only)**

The continuous representation has an additional level (*capability level 0: Incomplete*). At capability level 0, “An “incomplete process” is a process that is either not performed or partially performed. One or more of the specific goals of the process area are not satisfied and no generic goals exist for this level since there is no reason to institutionalize a partially performed process” (p 76).

At the incomplete level, the organisation or individual is not performing the specified process. It is possible that they are unaware of the process or that they do not see it as relevant for what they wish to achieve. Since the continuous representation focuses on the capability to perform individual processes, this is an allowable condition. When comparing the continuous representation with the staged representation, it can be seen that processes that are required for the higher maturity levels of the staged representation may be assessed as incomplete in an organisation that is rated at a lower level in the maturity hierarchy.

### **Level 1: performed (continuous) or initial (staged)**

At capability level 1 of the continuous representation, “A performed process is a process that satisfies the specific goals of the process area. It enables the work needed to produce work products” (p 77). At maturity level 1 of the staged strategy, “processes are usually ad hoc and chaotic. The organization usually does not provide a stable environment to support the processes. Success depends on the competence and heroics of the people in the organization and not on the use of proved processes” (p 79).

At the performed or initial level, the organisation or individual is performing an appropriate process for the specified task. The process has the potential to produce the required results. The degree of success is uncertain, as there is limited planning and uncertainty with respect to the quality of the product. There are no measurements in place to give certainty for planning or product quality.

### **Level 2: managed**

At capability level 2 in the continuous representation, “A managed process is a performed (capability level 1) process that has the basic infrastructure in place to support the process. It is planned and executed in accordance with policy; employs people who have adequate resources to produce controlled outputs; involves relevant stakeholders; is monitored, controlled, and reviewed; and is evaluated for adherence to its process description” (p 77). At maturity level 2 of the staged representation, “the projects of the organization have ensured that requirements are managed and that processes are planned, performed, measured, and controlled. The process discipline reflected by maturity level 2 helps to ensure that existing practices are retained during times of stress” (p 79).

The focus at this level is on managing the project including requirements, resources and time allocation. To move from level 1 performed to level 2 defined, Humphrey (1997) emphasises the need to identify what is currently being performed, the time being used to complete the task, and the

resources involved. Based on this gathered information, it is then possible to move to planned activities and tasks. Since Humphrey is focussing on the individual, he assumes that the requirements for the product of the process have already been defined.

### **Level 3: defined**

At capability level 3 of the continuous representation, “A defined process is a managed (capability level 2) process that is tailored from the organization’s set of standard processes according to the organization’s tailoring guidelines, and contributes work products, measures, and other process improvement information to the organizational process assets” (p 77). At maturity level 3 of the staged representation, “processes are well characterized and understood, and are described in standards, procedures, tools, and methods. The organization’s set of standard processes, which is the basis of maturity level 3, is established and improved over time” (p 80).

The focus here is on utilising organisationally defined processes. In the previous levels, the process would be built by the project team based on their own understanding of what needs to be performed (level 1) or as a result of the measurements that they have been taking on task performance (level 2). Now, the organisation has an agreed process model that is tailored to individual projects. This agreed process model may draw on industry standards. To move to maturity level 3, an organisational process model has to be defined and then used to guide individual projects. Humphrey (1997) draws on an industrial standard as a guide for process development.

### **Level 4: quantitatively managed**

At capability level 4 of the continuous representation, “A quantitatively managed process is a defined (capability level 3) process that is controlled using statistical and other quantitative techniques” (p 77). At maturity level 4 of the staged representation, “the organization and projects establish quantitative objectives for quality and process performance and use them as criteria in managed processes” (p 80).

The shift at this level is to assessing the quality of the outputs of the process. The capability maturity model does not define what suitable quantitative measures are. Its emphasis is that such measures are being gathered and can be used to assess the effectiveness of the process. Humphrey (1997) uses defect counts in program code and the savings gained by defect removal as quality and performance measures. Where the emphasis in prior levels was on obtaining measures to enhance project or process planning, the emphasis in this level is to obtain statistical data that can be used to aid in determining the effectiveness of the process in producing a quality work product and to identify potential areas for improvement.

### **Level 5: optimizing**

At capability level 5 of the continuous representation, “An optimizing process is a quantitatively managed (capability level 4) process that is improved based on an understanding of the common causes of variation inherent in the process. The focus of an optimizing process is on continually improving the range of process performance through both incremental and innovative improvements” (p 77). At maturity level 5 of the staged representation, “an organization continually improves its processes based on a quantitative understanding of the common causes of variation inherent in processes.” The focus is “on continually improving process performance through incremental and innovative process and technological improvements” (p 81).

Utilising the statistics of the previous level, it is now possible to make adjustments to current processes with the objective of obtaining incremental improvement. However more radical and innovative change is also possible through the examination of alternative processes and strategies to determine whether they produce better performance and product quality than the current process.

### **Summary**

Each level of the capability maturity model sees a change of perspective with respect to the process. At level 1, the process is the tasks that need to be done to achieve the required outcome. Monitoring and managing the process are not considered. At level 2, the process is seen as something that can be planned and managed. There is a sense in which the process is becoming a rule to be followed for

success. At level 3, there is recognition that of process can be applied and be tailored for a specific task. The selected process model may be followed more by rule with tailoring being the inclusion or exclusion of steps based on whether the desired outcome is required. At level 4, there is a move to assessing the effectiveness of the process in achieving the desired quality of result. The process is open to evaluation and critique. At level 5, the process is seen as continually open to change and improvement. The process moves to being a guide and not a rule. A changed process can be used but it is used in a context of being evaluated.

## **LEARNING PROCESS MATURITY MODEL**

With its focus on assessing organisational process maturity, some of the processes and levels do not seem to map easily to the individual. Humphrey (1995; 1997; 2000) has developed, in the personal software process (PSP), a strategy where the individual software engineer can apply the principles of the capability maturity model to their own work. Although Humphrey makes no attempt to redefine the maturity levels for the individual, he does identify the process areas that are relevant to the individual and develop a series of steps for implementing personal process improvement. He says that the role of the PSP is “to understand the CMM and know how to apply its principles” (Humphrey, 1995).

The following learning maturity levels are based on the capability maturity model (Chrissis et al., 2003). The focus on process is primarily as a series of activities rather than stages of development.

### **Learning maturity level 1: Initial or immature**

At level 1, initial or immature, the learner relies on direction from the learning facilitator (i.e. is a dependant learner) or grabs at random from a bundle of known learning strategies. The success of any learning venture is either dependant on the guidance given or on the accidental selection of an appropriate strategy. There is little structure to how learning is carried out. An immature learner tends to focus on memorizing facts or seeking right solutions (dualistic right or wrong thinking)(Perry Jr, 1968) and may not recognise the thinking processes or strategies of the subject area. Most often the learner will see learning as occurring only in formal learning situations. This doesn't mean that they are not learning outside these situations. Rather their perception of learning is that it occurs in a formal setting.

### **Learning maturity level 2: Managed**

At level 2, managed, the learner has identified a number of strategies that have been successful in the obtaining the desired learning outcomes. At this stage, the strategies are not clearly defined but they are things that the learner has become accustomed to doing when endeavouring to learn and they have delivered success on a reasonable number of occasions. The learner is tracking how they allocate their time to the learning strategies and planing how they will approach their learning.

The learner possibly with the assistance of their learning facilitator is identifying their current knowledge, the desired learning outcomes, learning strategies to use, and required resources. They are able to plan an approach to achieving the desired learning outcome. Learning may still be occurring primarily as a memorise, recall, and apply level of cognitive skill. The quality of the learning is not being assessed rather the effectiveness of the plan is based on a perception of success against the defined learning outcomes.

### **Learning maturity level 3: Defined**

At level 3, defined, the learner has a number of strategies that they use on a regular basis. They are defined in the sense that the learner sees these strategies as being used consistently within the subject area. The learning strategies may be linked with some model of learning or learning preferences. At this level of maturity, the learner may be quite stubborn to change insisting that learning opportunities must be provided that satisfy one of their known strategies or learning preferences.

The learner is recognising that the subject area solution possibilities are drawn from processes that reveal them and are supported by subject area reasoning. The learner may depend the learning facilitator for the processes, subject area reasoning, and assessment of learning.

#### **Learning maturity level 4: Assessed**

At level 4, assessed, the learner is beginning to be able to measure the effectiveness of their learning. At this level, they are beginning to see that their known strategies are not always the most efficient and are seeing how to assess their strategies for different learning tasks. Because they are beginning to measure the effectiveness, they are also more open to new strategies. The learner is developing a degree of independence in their learning situations.

At this level, the learner is open to change with respect to how they perceive learning and the outcomes of learning. They become more focussed on building conceptual frameworks and developing the skills for thinking and reasoning in the subject area. The quality of learning is perceived not simply by how much has been learnt but by the ability to reason and evaluate the thinking processes used in the subject area. At this level of maturity, the learner is beginning to assess their outcomes of their learning with a high degree of accuracy.

#### **Learning maturity level 5: Optimizing**

At level 5, optimizing, the learner has become quite flexible in the use of learning strategies. When a learning situation presents, the learner evaluates strategies and selects from their repertoire and selects a strategy that is the most appropriate for the given circumstances. The learner has developed a clear understanding of the effectiveness and appropriateness of each learning option they have available. They are also keen to expand their repertoire so that they can face new and more challenging learning situations. There is a desire for ongoing improvement of their learning and understanding.

At this level, the learner is not dependant on specific learning situations or on direction. They see learning possibilities all around them and take on the challenges that are available. Conceptual frameworks, thinking skills and reasoning in the subject area are the primary focus. So-called facts, solutions, processes, and reasoning are not taken at face value. Everything is open to evaluation and interpretation. The learner seeks to commit to their current understanding and thinking processes based on sound supporting reasoning.

### **PROPOSED USAGE**

The next stage is to develop a set of tools that can be used with the normal teaching cycle in an undergraduate first and second year programming papers. The tools will be designed to assist the learner to move through the maturity levels.

The first set of tools will be aimed at moving the learner from learning maturity level 1 (initial or immature) to learning maturity level 2 (managed). The tool will be diagnostic in the sense of helping the learner to discover their current practices and to plan improvement. The tools will involve time recording, learning strategy identification, project planning, assessing current knowledge levels, and defining learning requirements.

The second set of tools will be aimed at moving the learner from learning maturity level 2 (managed) to learning maturity level 3 (defined). The tools will involve presenting possible learning process strategies and the contexts in which they apply.

The third set of tools will be aimed at moving the learner from learning maturity level 3 (defined) to learning maturity level 4 (assessed). The tools will involve assessment of the quality of learning achieved by using a learning strategy (Biggs, 1999; Biggs and Collis, 1982) and where the learner is with respect to models of learning (King and Kitchner, 1994; Mezirow, 1991; Mezirow, 2000; Perry Jr, 1968).

The fourth set of tools will be aimed at moving the learner from learning maturity level 4 (assessed) to learning maturity level 5 (optimizing). The tools will involve being able to identify weaknesses or defects in current learning strategies and to identify learning strategies that address those weaknesses and reduce the defects.

### **CONCLUSION**

The model proposed forms the basis for the development of a learning process maturity model. It is process focussed in that it concentrates on the planning and managing the strategies of learning rather

than the stages of development. It is recognised that as a learner moves through the stages, there will be a change in attitude with respect to the objectives of learning and as a consequence the assumptions about the use of learning strategies.

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