Applying Capability Maturity Model to Curriculum Design: A Case Study at Private Institution of Higher Learning in Malaysia

Thong C. L., Yusmadi Y. J., *Member, IAENG*, Rusli A., and Nor Hayati A.

***Abstract* -Capability Maturity Model (CMM) was applied as a process improvement model not only in software industry but also in education sector. In this study, Capability Maturity Model is applied to investigate whether process improvement can be generated in designing curriculum for Institution of Higher Learning. Therefore, a model which contains a set of key process areas and best practices is constructed and presented based on the literature study, and a case study is carried out in a private Institution of Higher Learning in Malaysia. It is discovered that the model offers a means for institution to self-assess the curriculum design process and may put forward guidance in designing a sound curriculum. The model also may help the institution to determine their maturity level; whether the process has obtained any maturity level and subsequently they are guided to complete the process before moving to next level. In addition, the results may also help the institution to be informed of future improvement process.**

***Index Terms* - Capability Maturity Model, Curriculum Design Process, Curriculum Designer, Institution of Higher Learning**

I. INTRODUCTION

The significant challenge faced by most curriculum designers is designing a sound curriculum that complied with best practices and quality standard fixed by the accreditation body. Despite much effort put in designing curriculum, uncertainty remains over whether the effort spent is resulting in sound curriculum [1]. It is believed that curriculum design process plays an important role in helping to design a sound program of study.

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Thong C. L. is a PhD candidate at Faculty of Computer Science and Information Technology, Universiti Putra Malaysia, 43400, Serdang Selangor, Malaysia. (e-mail: chloethong@ucsi.edu.my).

Yusmadi, Y.J., and Rusli, A. with the Department of Information Systems, Faculty of Computer Science and Information Technology, Universiti Putra Malaysia, 43400, Serdang Selangor, Malaysia. (Phone: +603-89471760, fax: +603-89466576, e-mail: yusmadi@fsktm.upm.edu.my, rusli@fsktm.upm.edu.my).

Nor Hayati, A. is with the Department of Science and Technical Education, Faculty of Educational Studies, Universiti Putra Malaysia, 43400, Serdang Selangor, Malaysia. (e-mail: nalwi@putra.upm.edu.my)

In software development, the process of developing software product is important as it helps to produce quality product. Similarly, the process of designing curriculum is crucial, as curriculum design is an important phase in curriculum development. Curriculum design and software development bear some similar common features. Both possess complex activities and development life cycle and emphasis on design quality. The success of both domains is attributed to the good structure and the used of best practices i.e. a process that helps us to structure and do things right [2].

Despite neglecting good software practices, a software developer might produce good software at the end. The process by which software is developed is not directly visible in the quality of end product [2]. However, curriculum designers can indirectly influence the end product of their work. Although the actual learning outcome is not up to the designers but the students, good structure and best practices play instrumental roles in the success of the design process. Therefore, curriculum designers need to give great emphasis in the design process. In this study, a process is defined as a domain with a set of activities, practices and transformation that faculty may use to improve the quality of the curriculum [3].

II. BACKGROUND

A. Related Work

CMM is a maturity model used in software engineering and it was originally developed in the 1980s by the U.S. Department of Defense, Software Engineering Institute (SEI) at Carnegie Mellon University as a method for objective evaluation of contractors for military software projects [4]. The key to CMM model is it is designed to provide good engineering and organizational management practices "for any project in any environment" [5]. It achieves this through a structure that breaks each level into a number of process areas. Each of these areas is in turn organized into a number of sections called common features, which are used to organize the key practices that accomplish the goals of relative process areas [6]. Refer to Table I for CMM maturity levels.

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There has been quite a history in the application of CMM in education. There are many maturity models constructed based on CMM in the past to alleviate the shortage of quality standard in education. Among the various maturity models, some are process improvement models used by higher education to support online course design and curriculum design for Information system education, while others are process improvement models for other areas such as e learning [3],[7],[8]. Some models are successfully used by higher education to improve their design quality processes. Even though there are many maturity models constructed to support and improve quality design process, there is a shortage of maturity model providing self-guidance to curriculum designers so that they know which maturity level they are in and whether the processes has reached maturity level and are guided to complete the process before moving to next level. By doing so, the design process will be shortened and the quality of the process will be increased. Difficulties such as time and efforts for designing curriculum will be significantly reduced. This will evenly improve product (curriculum) design quality.

TABLE I
CMM MATURITY LEVELS (SEI, 1995)

Maturity Level	Brief Description
Initial	The software process is characterized as ad hoc, and occasionally even chaotic. Few processes are defined, and success depends on individual effort and heroics.
Repeatable	Basic project management processes are established to track cost, schedule, and functionality. The necessary process discipline is in place to repeat earlier successes on projects with similar applications.
Defined	The software process for both management and engineering activities is documented, standardized, and integrated into a standard software process for the organization. All projects use an approved, tailored version of the organization's standard software process for developing and maintaining software.
Managed	Detailed measures of the software process and product quality are collected. Both the software process and products are quantitatively understood and controlled.
Optimized	Continuous process improvement is enabled by quantitative feedback from the process and from piloting innovative ideas and technologies.

B. The Structure of Curriculum Design Maturity Model (CDMM)

CDMM is a model constructed based on literature study. The construction of CDMM is based on two models, which are online course design maturity model (OCDMM) and curriculum redesign process improvement model for Information system education proposed by Dennis and Minnie [7] and Neuhauser [3] respectively.

CDMM's levels of process capability are presented in Table II. The model defines five levels of process capability and each process is broken up into a set of key practices, which are assessed at each level using a five-point scale (not adequate, partially adequately, moderately adequate, adequate and fully adequate). For the interest of this paper, the processes were assessed using a holistic approach and a single result is obtained instead of detailed analysis.

TABLE II
CURRICULUM DESIGN MATURITY LEVEL – LEVELS OF PROCESS CAPABILITY

Maturity Level	Brief Description
Initial	The curriculum design processes are characterized as ad-hoc and occasionally is even chaotic. Lacking in policies and practices for controlling curriculum design process. Although a few processes are defined, the success depends on individual effort.
Repeatable	Basic curriculum designs processes are established such as develop key practices that allow it to repeat success and discard those that hindered success. It is restricted to course level rather than broader program level. The focus of this level is to design a clear and measurable learning outcome for each course.
Defined	The curriculum design process for course-level activities is documented, standardized and integrated into a standardized design process for the program. All courses use an approved, tailored version of program's standard curriculum design process for designing and reviewing curriculum. The focus of this level is to define standardized process at course level, alignment of key process areas within the courses itself and between streamlined courses to the program.
Managed	Detailed measure of curriculum design process and curriculum quality is collected. Both curriculum design process and curriculum (product) are quantitatively understood and controlled. The focus of this level is to ensure both the quality (alignment) of course learning outcomes within the courses and programme learning outcome.
Optimized	Continuous process improvement is enabled by quantitative feedback from the design process and from piloting innovative ideas. The focus of this level is continual improvement in the three KPAs of the curriculum design process.

For the designing of new curriculum or redesigning of existing curriculum, the process starts from initial level. The reason is CMM was originally designed for stage-based improvement, the concept applied to evolutionary improvement of each process. Process capability is a means to predict the most likely results. If a set of best practices within a process is followed, then we can predict good results. For example, literature shows that student performance is better when curriculum alignment is in place. Therefore, well-aligned curriculum will produce the potential for high performance by students than poor-aligned curriculum.

This study focuses on curriculum redesign process of an academic program in the field of software engineering. Henceforth, the curriculum is known as 'programme' and the modules within the program are known as 'courses'. 'Programme' means an arrangement of courses that are structured for specified duration and learning volume to achieve the stated learning outcomes and usually leading to an award of a qualification [9]. Module is a unit of learning and teaching also described as subject or course or unit in a programmed [10]. In this paper, curriculum and programme will be used interchangeably. Next, a brief description of each levels of process capability will be presented in the following sections.

III. METHODOLOGY

In this paper, methodology used is composed of two parts. Firstly, the construction of CDMM is based on literature study and secondly, pilot testing is conducted to test the model using template which contains assessment

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criteria to assess the existing curriculum in order to determine the level of maturity reached during the curriculum redesign process. The assessment criteria are developed from benchmarks. These benchmarks are provided in the documents namely Guidelines to Good Practice: Curriculum Design and Delivery (GDP:CDD, 2010), Code of Practice for Programme Accreditation [9], Programme Standard for Computing (PS) [10], confidential documents obtained by the institution including ISO documents and literature review. The approach used for curriculum redesign in this study is 'bottom-up' approach with 'top-down' support perspective from the code of practice for programme accreditation [9]. A second perspective which is 'horizontal alignment 'could be introduced into curriculum redesign process to ensure courses are properly aligned in the three identified key practices. However, the second perspective is beyond the study scope of this paper.

As with the CMM processes, CDMM defines five levels of process capability as shown in Table II. Each process is broken up into practices, which are assessed at each level using a five-point scale (not adequate, partially adequately, moderately adequate, adequate and fully adequate). A template that contains assessment criteria is developed from benchmarks and serves as a measurement of the model. In fact, the assessment criteria are used to reflect the curriculum redesign process. These processes are given on the left-hand column in Table III.

Although it is found that the institution has an ISO procedure for revision of existing curriculum, it is only covered the curriculum revision process such as the approval process for curriculum revision upon completion of the review exercise and it does not cover the curriculum redesign process at program or course level. The institution is using ISO 2001:9000 for the teaching and learning process. Although ISO procedures are in place, they do not reflect the actual curriculum redesign process at programme and course level.

IV. THE RESULTS

A. Background to Pilot Test of CDMM

The model was tested to a bachelor degree level programme, which is offered nationally and internationally. The study mode offered are on campus and in a conventional classroom setting, which is classroom sessions taught by lecturers. There are approximately 100 students in the on-campus class. The programme is supported by online course materials and electronic forms of communications, such as Learning Management System (LMS). This programme introduced in 2003. The original programme model after ACM model degree level curriculum and the curriculum designers also align the programme with both the ACM model and industry requirements at that time of development. Since then, the programme has been upgraded on regular basis. For example, as new software development methods came into the prominence, courses are either revised or added to reflect them. In recent years, the faculty also looked at the constructive recommendation given by the industry advisory board and external examiners so that the programme will be instituting better coverage of the lacking areas in the program. These are the several program improvement opportunities surfaced with this exercise.

B. Results of Pilot Test of CDMM

The results from the pilot test of CDMM are presented in Table III. Summary results are presented in this section in order to clearly indicate where it helps the institution to determine the maturity level they are in, whether the process has reached maturity level and how curriculum designers are guided to complete the process before moving to next level. In addition, the results may also help the institution to be informed of future improvement process. Therefore, detailed analysis of a particular process in each maturity level is generally not as useful as the high-level overview in this study.

The initial level reflects the ad-hoc nature of curriculum redesign process and the support around it. For example, curriculum designers design courses independently and the guidance provided by the faculty is limited during the redesign process. However, some relevant policies and practices are provided and explained by institution for controlling the curriculum redesign process. The result shows that the institution is still at the initial maturity level in curriculum redesign process. In order to move to the next level, initial level needs to reach maturity level by fulfilling the assessment criteria set at this level.

At the repeatable level, basic curriculum redesign process may establish. The institution is rather weak in repeatable level as basic management of curriculum redesign process has yet to be established such as course level guidelines and compilation of best practices for the process. At this level of maturity, the process was still centered on the individual courses. According to the guidelines of CMM, in order to reach the next level, it is necessary to encompass the entire programme.

In order to fill up the limitation in repeatable level, defined level is introduced. Defined level is not focus on the success of individual courses, but the entire programme. It is also addressed the concern about alignment of programme learning outcomes to educational objectives and vision and mission of the IHL. Faculty is more involved at this level to the programme-wide coordination to meet the educational goals set by the IHL. At the same time, peer review process may be introduced to ensure the alignment among the streamlined courses in terms of course learning outcomes and content. This implies that courses are more aligned with programme learning outcomes and reduce the overlapping of course learning outcomes among the streamlined courses. For example, the first object-oriented modeling course (OOM1) may introduce initial object-oriented concepts used in analysis and design; and second object-oriented modeling course (OOM2) may provide students with an understanding of more advanced object-oriented analysis and design concepts and principles, with particular reference to Unified Modeling Language (UML).

In order to reach this maturity level, a clear understanding among curriculum designers is required and the streamlined courses are interdependent, and aligned to the programme learning outcomes. In order to have such achievement, department-wide course coordination and departmentalize (institutionalize) a peer review process are suggested. Although the institution has not reached this level of

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maturity, it is encouraged to adopt these practices during the curriculum redesign process to ensure the standard and quality of the programme.

Next, we began moving towards attained the "Managed" level of CMM. Metrics can be used as a statistical quality control measures. Based on the study, quantitative evaluation of programme quality has not been practicing by the institution. It is suggested this process be evaluated based on the achievement of programme learning outcomes and present in the form of metrics quantitatively. Some measurement instruments such as standard evaluation form is developed for normalizing alignment of courses.

At optimized level, the institution will be focusing on continuous process improvement. At this level, the curriculum committee has been formed to identify three to five areas that will be targeted for improvement in the academic year [9]. The institution involved in this study, has instituted some measures across programme learning outcomes in response to accreditation standard.

V. DISCUSSION

Through this study, it is discovered that there are some advantages provided by CDMM and they are as follows. Firstly, CDMM could provide a roadmap for IHL to improve curriculum redesign processes. Most curriculum designers use ad-hoc approach where the redesign process has more to do with individual work rather than institutional planning. Many IHL might need the roadmap to guide them.

Secondly, CDMM also encourages institution extensively involved in long term institutional planning. The advantage of this report is that it outlines an overview of overall curriculum redesign process without examining the detailed report.

Thirdly, using the CDMM enables the faculty to enhance the ability to benchmark its ability and prioritize necessary improvements in its current practices.

Lastly, CDMM enables curriculum designers to conduct informal self-assessment and identify their own level in terms of which maturity level they are in, and guide them to complete one process before moving to the next level. By passing through the process, future improvement process may also be identified.

VI. CONCLUSION

The proposed model was tested on the private IHL as a pilot study. The result shows in this paper are a starting point and more improvement is needed to ensure that the model helps the curriculum designers to develop a better programme of study. However, in future more participation from other IHLs is needed to validate the model and also to identify more practices and improvement processes.

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TABLE III
TEMPLATE FOR ASSESSMENT OF PROCESS CAPABILITY AND RESULTS FROM PILOT TEST

Initial: Ad-hoc or chaotic management of curriculum redesign process						
Key Practices at initial level		1	2	3	4	5
A1. ISO	Courses are re-designed based on systematic and planned process			√		
A2. ISO	Institution clearly communicate how curriculum re-design processes should be used during the courses or programme redesign		√			
A3. ISO	Guidelines in managing and defining curriculum redesign process are provided by institution		√			
A4. ISO	Curriculum designers are guided in a proper methods of redesigning curriculum by faculty		√			
A5. COPPA	Curriculum designers are subject matter experts in the design process in redesigning the courses			√		
A6. LR	Courses reviewed and redesigned interdependently	√				
A7. COPPA	Courses are redesigned to reflect the programme objectives and learning outcomes			√		
A8. LR	Quality and scope of each course are based on objectives set collectively by curriculum designers	√				
A9. COPPA	Policies and practices are provided and clearly explained by institution for controlling the curriculum redesign process			√		
Repeatable: Basic management of curriculum redesign process are established						
Key Practices at Repeatable level		1	2	3	4	5
R1. ISO/COPPA/GGP:CDD	Courses are re-designed based on policies and a set of practices			√		
R2. COPPA	Guidelines for programme standard at course level are used appropriately and adequately during curriculum re-design process		√			
R3. PS	Course learning outcomes are reviewed based on programme standard				√	
R4. PS	Course content are reviewed based on Software Engineering Education guidelines	√				
R5. LR	Course learning outcomes are measurable and constructed based on learning domains of Bloom Taxonomy		√			
R6. PS	Integration of streamlined courses are possible		√			
R7. ISO	Curriculum designers have access to sufficient resources required during the redesign process			√		
Defined: Curriculum redesign process is documented, standardized and integrated into a standardized process						
Key Practices at Defined level		1	2	3	4	5
D1. LR	Curriculum redesign process for course-wide focus has moved to programme-wide focus		√			
D2. LR	Programme-wide coordination is developed		√			
D3. LR	Peer review process is introduced	√				
D4. LR	Introduce standard template or form for the curriculum redesign plan	√				
D5. ISO	Curriculum designers have convenient access to the necessary documents			√		
D6. ISO	A structured system in place to address curriculum designers' problems during the redesign process	√				
D7.	A documented set of practices are used to determine the standard and quality of					

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PS	the programme	√				
D8. ISO	A documented redesign plan is in place to ensure the standard and quality of the programme	√				
D9. ISO	Faculty agrees upon the reviewed curriculum upon completion of redesign process				√	
L4 ISO/COPPA	The Intuition provides support for building and maintaining curriculum redesign process		√			
Managed: Detailed measure of curriculum redesign process						
Key Practices at Managed level		1	2	3	4	5
M1. LR	Metrics are developed and tracked overtime, possibly using statistical quality control measures	√				
M2. LR	Measure across programme learning outcomes in response to accreditation standard		√			
M3. LR	Quantitative assessment of programme learning outcomes	√				
M4. LR	Quantitative assessment of course learning outcomes	√				
Optimized: Continues process improvement						
Key Practices at Optimized level		1	2	3	4	5
O1. COPPA	The objectives of continuous improvement are identified (preferably quantitative)	√				
O2. LR	Use of objectives as target for curriculum improvement	√				

Note: 1= not adequate, 2 = partially adequate, 3 = moderately adequate, 4= largely adequate, 5 = fully adequate

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