A Strategy, Implementation and Results of a Flexible Competency Based Curriculum.

By Yma Pinto

Computer science education faces two major problems – the continuous evolvement of the discipline itself and the issue of appropriate employment of graduating students. Instructors and educators need to periodically reinvent and restructure their curriculum to keep their learners abreast. The question is, therefore: How do we design a curriculum that is flexible, yet targeted towards the learner acquiring the necessary knowledge and skill set to make him/her "employable"? An effective approach is to structure the curriculum by defining the requisite competencies as the instructional goals and subsequently defining the conceptual requirements to achieve these goals. The results of the effectiveness of this strategy are analyzed in the paper.

* * * * *

1.0 INTRODUCTION

Continuous and significant changes in computer science technologies create considerable pressure on academic institutions to keep the curriculum current and relevant. Operationally, it requires frequent revisions of course design. Academically, it requires research and understanding on how students learn new topics and how these topics are interrelated. When a systematic framework is provided to develop and deliver courses and supplementary activities, students will learn more effectively. The need to provide varying levels of knowledge to different target populations is a challenge to educators. Curriculum designers need to identify the core competencies that a student is required to achieve after completion of the course, and the effective learning processes and strategies characteristic to that discipline. This differs from the traditional methodology which focuses on imparting a generalized knowledge base that might prove useful sometime in the future. The issue that this paper addresses is the design of a curriculum that is flexible, yet targeted towards the learner acquiring the necessary "knowledge base" for sustainable employment. This kind of a framework results in multiple entry and exit points into the system and can be flexible enough to accommodate inter-disciplinary students with multiple skills or competencies.

Because firms shift their IT strategies and tactics in response to competitive conditions, they want employees with knowledge in more than one skill area. This is emphasized by [15] *"We need well rounded IT graduates who know how to apply knowledge and are adaptable. Traditional computing education is dead. Transitioning to a new model is a challenge and one that certainly will take strong leadership from both education and industry working together."*

This paper looks at a curriculum design, primarily based on competencies, and which can be customizable at an individual level. Section 2 looks at some of the relevant articles and work in this area. Section 3 provides a general framework for computer science courses and Section 4 uses the framework to design a core course in Computer Science. This section also analyzes the performance results of the partially implemented framework. Section 5 concludes with the requirements for future enhancements in the design.

* * * * *

2.0 RELATED WORK

When a curriculum is first developed, its designers must articulate intended learning outcomes that align with competencies. Academic administrators must ensure that our academic programs deliver on the student performance in the expressed competencies. [4] And [5] make a mention that quality curriculum can only be created by linking curriculum design and assessments to the needs of the workplace. More recent research papers illustrate a similar outlook [9]. Facing such pressures and trends, the competency concept should arguably be the foundation for the new curriculum design. [11] Proposes a high level framework but does not really take into account the needed flexibility required in a rapidly changing curriculum.

A student could learn through "raw discovery" and finally attain the needed skill to perform the task required. Although effective, this is not an efficient method of learning. The student may not have realized "the reason" behind a "drawn conclusion" and thus, may not be able to analogize or propagate the skill obtained. This is detrimental to his future learning growth curve. Any Learning Material prepared – irrespective of the mode being classroom delivery or e-learning, must propound a procedural method of learning, This enhances the students' ability to predict, abstract, evaluate, discover and learn at a faster pace.

Initial research in the formulation of competencies in education may have started as early as 1977, but several conceptual and technical issues still exist. There is little consensus on the meaning of these concepts among the many researchers and authors [13] and in practice, various institutions use different descriptions. Designing competence-based curricula processes and learner centric activities, and assessment procedures can be effective for all stakeholders only when competencies are defined without ambiguity. This paper addresses these issues by illustrating the design, implementation and assessment of an industry oriented course in computer science. The paper also analyzes the effectiveness of a pilot study of the design.

A Strategy, Implementation and Results of a Flexible Competency Based Curriculum

continued

* * * * *

3.0 THE FRAMEWORK

Competency, an interpretation relevant to all stakeholders, can be defined as having the necessary skill or knowledge to perform a task successfully. "Competencies are personal capabilities that are demonstrated through measurable knowledge, skills, abilities, and personal attributes, which can contribute to enhanced employee performance and, ultimately, to the individual's and organization's success". Additionally, [8] adds, "Competency is a requisite ability and quality of a student within an academic program, the achievement of which indicates the students capability or qualification in the area of competency". This emphasizes the fact that education should focus on competency level training and assessment and ensuring a students acquisition of knowledge, skills and persona that makes them "industry ready" at the time of recruitment.

Instructional Material design and content creation should take into account Bloom's Levels of Learning [Bloom et al]. Since knowledge is assimilated at different levels, learning modules should be constructed so as to take the learner from an elementary knowledge base of information and concepts through application and analysis of the knowledge, and finally towards synthesis and evaluation. In the competency based model, a proscribed competency (consisting of concepts, with a pre-requisite conceptual knowledge base) is the instructional goal - and the curriculum presentation, learner guidance, practice and evaluation strategies should be targeted towards acquiring this particular goal.

Designing the curriculum thus results in these steps:

i. Identify job opportunities and duties involved.
ii. Identify personality traits (soft-skills) required for the job.
iii. Identify the competencies required to perform the job.
iv. Identify the knowledge, know-how and current skills required to achieve these competencies.
v. Identify corresponding subject concepts (theory) to acquire the knowledge base required.
vi. Identify assignments (practice) that enhance the "know-how" of the subject.
vii. Identify the skill set (the means) required to perform the assignments
viii. Identify text and reference materials whose subject objectives match the knowledge required in (v), (vi) and (vii) above.
ix. Design assessments that can check a candidate's knowledge at various learning levels for a given competency

Although the core fundamental conceptual knowledge in IT remains the same, technological advances in computer science are varied and rapidly changing. While designing a curriculum for an IT related course, knowledge about a particular software or tool is not sufficient. The knowledge that is needed is about modeling the problem itself first (the domain knowledge and the analytical knowledge), thinking which IT tool to use and how, and then applying a combination of them all. IT professionals are asked to master new skills that did not exist a few years ago while still performing old skills. Hence the skill set that the learner acquires must be what the industry currently requires. The curriculum design must be flexible enough to take this into account. [2] Does a relevant study that brings out the issue of applicability of knowledge that students receive when a course is done in a traditional manner in most educational institutions. The content delivery of most of the IT courses is done through review / demonstration of the tool itself (functionalities, menus etc) which directly follow contemporary literature approach on the subjects. This approach to lecturing does not deliver the intrinsic value it should. The most important knowledge required - that of finding the right feature of a tool to solve a specific problem - is missing.

Facing such pressures and trends, the competency concept should arguably be the foundation for the new curriculum design. A Conceptual Mapping Diagram that reflects the learning material required to acquire the competencies will need to show the pre-requisites for certain concepts that lead to a specific, and well defined, competency. Further, the learning material needs to be structured as:

Information: Material that does not require learner guidance or practice and can be assigned to students as self study material.

Knowledge: Concepts that must be covered in a pre-requisite order, and for which learner material and guidance needs to be provided.

Know–How: Assignments and practice to consolidate the concepts learned.

Skills: A subset of the current technologically viable skill set that the learner needs to acquire while performing the practice and enhance his particular domain expertise.

Since the concepts are formulated at different levels of learning, assessment should be targeted at finding the competency level of the learner at the Knowledge Level Base that he/she has currently opted for. Rating the level of competency is not only for qualification but also helps in stimulating the students need for further development. This approach differs from the Traditional Method of Instruction delivery and assessment where material is focused on a particular subject area of knowledge acquisition and does not always cover the entire breadth of knowledge required for a competency. Further, in the traditional delivery, the knowledge that is learned is supposedly to be proven applicable in the future, even though the knowledge is not presented within a specific context or with the intention of training the student for a specific occupation.

The grading scale in which a student can readily identify with can be used:

1. Knows something but is very confused (cannot justify the answer properly);
2. Knows something but some confusion still exists (answers may not be optimal, but can reason out the answer);
3. Sufficient amount of knowledge (can analyze and identify optimal solutions; has a clear understanding and has marginal errors in solutions);
4. High Level of Knowledge (can generate and evaluate multiple alternative and accurate solutions.

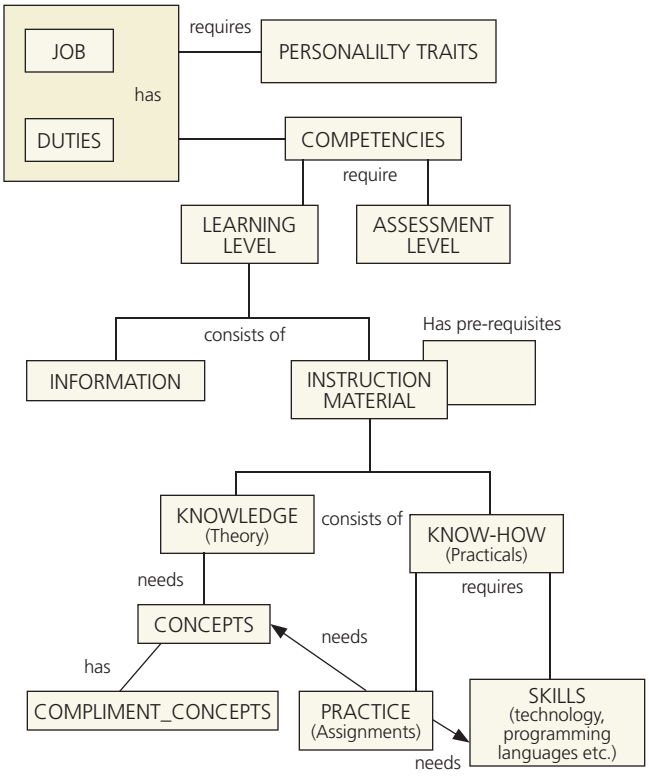
Scales of 0 and 1 would imply that the learner cannot perform the competency (implying a repeat of the Learning Process). Scales of 2

and 3 imply that the learner can perform the competency but needs guidance. A Scale level of 4 would mean that the learner can perform the competency efficiently. To be able to pass the course, the learner must achieve at least a Scale of 2 in all the competencies stated in the course. A candidate can seek to improve his/her grade point in any competency. This is another point of difference from the Traditional Method of assessment where the entire evaluation is done at the end of the learning cycle, and the grade earned once lasts for a lifetime.

Diagram to be interpreted as:

A job type has many duties to be performed which need not be unique across various jobs.

To be able to perform tasks efficiently, candidates need to imbibe certain personality traits and acquire certain competencies. Students desirous of obtaining jobs can be assessed on the competencies acquired through learning, by an evaluation targeted at different levels of understanding. The depth of learning can be acquired at 3 different levels – Elementary, Intermediate and Advanced.



Information differs from Instruction in the sense that it does not require presentation and practice. It may be facts, definitions etc .

Instruction requires learner guidance in the form of knowledge (assimilated concepts) and practice (assignments in the real or simulated environment).

Instruction material requires pre-requisite concepts for its understanding

While performing the assignment, a student could acquire a particular skill (from a varied skill set that can be used). He should be able to analogize this skill set to learn a similar skill and enhance the existing ones.

Figure 1: Diagrammatic Representation of proposed curriculum design framework.

A High Level Diagrammatic Representation of the proposed framework that helps visualizing the objects involved in designing the curriculum is shown in Figure 1.

This structure also lays an emphasis on the way in which a student assimilates knowledge – a reasonable "workload" being a pre-condition to deep learning [1]. Researchers also emphasize skill based approach to competency development as certain skills are critical to a firm's organizational capacity. In contrast, the traditional curriculum defines an approved set of courses and a fixed set of skills within a well-defined but inflexible structure. While designing instructional transactions in the competency-based model, the learner should be assessed individually for each competency.

Although the core fundamental conceptual knowledge in IT remains the same, the advances made in the technological arena are varied and rapidly changing. Hence the skill set that the learner acquires must be what the industry is currently using. The curriculum design must be flexible enough to take this into account. Further, when identifying concepts, the granularity is important – it should not lead to a diverged focus on the part of the learner or leave the learner disoriented. The relationships between concepts, complementary concepts and pre-requisite concepts should be clearly identified. [6] looks at a concept as "A semantic meaningful unit of instruction with a specific intent type and a matching instruction and evaluation type"

Most organizations, while recruiting candidates, lay an emphasis on the soft skills of the professional, and many technically savvy candidates fail to procure jobs if they do not have the required personality traits commensurate with the job. A professionally designed curriculum would require inculcating two main types of competencies:

(i) Professional competencies that relate to the "knowledge base" required and the ability to use this knowledge in the related work area.

(ii) Personal competencies that represent a set of skills, attitudes and values that enable the professional to work efficiently and adapt to his present environment.

* * * * *

4.0 THE DESIGN

In this paper, each Level of Learning Material is considered to be constructed into Modules based on concepts required for certain competencies and taking into consideration Blooms Learning Knowledge Levels. The conceptual content of the course is separated into "Elementary Learning Material" (comprising Knowledge Levels 1 and 2), "Intermediate Learning Material" (Knowledge Levels 3 and 4) and the "Advanced Learner Material" (Knowledge Levels 5 and 6). If desired, a learner can progress to a Knowledge Base at a higher level of learning after having been successfully assessed for the Learning Material at the lower level. This also allows a learner multiple entry and exit points into the system, providing a flexible knowledge learning structure. A learner on assessment

would acquire a particular grade which determines his/her level of competency in a specific conceptual area of knowledge. This grade can be subsequently improved if desired. As noted by [10], IT professionals who have multiple competencies are considered to be more valuable.

Any activity that involves manipulation of data of any kind and at any level requires some knowledge of data management. While databases are often created and maintained by information technology professionals, for today's business needs, all professionals would need to manipulate their own data. That is why it is mandatory that students understand how data management systems are used to design, build and run modern database applications. The Model curriculum guidelines for Under Graduate programs [7] recommends that students in any discipline of study require working knowledge in at least the areas of word processing, spreadsheets, Internet access, database management and external database retrieval. Students offering a minor in Information Systems must necessarily undergo a course in database design and information retrieval (among other courses). According to [14], outside of programming, competency is highly prized in operating systems, networking and web management, database design and SQL, systems implementation and testing. The study of DBMS is still evaluated as being very important even though various technologies have been launched in the last 10 years [12].

A student of IT, at the end, should be able to evaluate a business situation and build a database application for it. They should thus master three specific areas of knowledge – Data Design, Manipulating and Presenting data (and the consequences thereof) in a multi-user and heterogeneous environment, and Programming. On the other hand, an interdisciplinary student would need to know how to extract data from a database in his specific domain of knowledge and present the data effectively.

At the top echelon of career opportunities in Data Management is the DBA. Since the DBA is required to acquire all conceivable competencies in the area of data management, the curriculum design strategy first needs to determine the competency domains and the role of a DBA. These domains can then be filtered (by locating suitable entry points and pre-requisites) for other careers. The focus of the curriculum is on the core functionality required and not on the various, possibly conflicting, extensions possible. Adaptations that complement the design can be added later.

Although personality traits are important in recruiting a candidate, the perspective of this paper is to arrive at competencies in the design of syllabi for an IT related subject. This does not imply that IT related jobs do not require soft skills. On the contrary, many organizations consider it a very important factor whilst selecting candidates for recruitment and many technically savvy candidates fail to procure jobs if they do not have the required soft skills commensurate with the job.

A good way to visualize the curriculum would be to map the concepts in a diagrammatic way showing the organization, pre-requisites and relationships between the various concepts (conforming to the way learning takes place). This not only aids in preparing the guiding material for presentations and assignments, but allows for a continuous and effective assessment for a particular competency

AUDIENCE	Naïve End Users	Interdisciplinary Students, Sophisticated End Users,	DB Designers, DB Architects, Application Developers, Programmer Analysts, UG Teachers	Data Administrators
KNOWLEDGE BASE	Module 1 (Overview of DM) Part A FDM– EL (L1) Module 3 (Application Dev) Part A DMR– EL (L1)	Module1 (Overview of DM) Part A FDM –EL (L1) Part B DBE – EL (L1) Module2 (App Dev) Part A Analysis– EL (L1) Part B Design – EL (L1) Module3 (Using the DB) Part A DMR – EL (L1) Part B EDBP- EL (L1)	Module 1 (Overview of DM) Part A FDM – IL (L1, L2) Part B DBE – IL (L1 , L2) DS – IL (L1) Module 2 (Application Dev) Part A Analysis – IL (L1, L2) Part B Design – IL (L1, L2) PDB –IL (L1) Module 3 (Using the DB) Part A DMR – IL (L1, L2) Part B EDBP – IL (L1, L2)	Module 1 (Overview of DM) Part A FDM – AL (L1, L2 ,L3) Part B DBE – AL (L1 , L2, L3) DS – AL (L1,L2) Module 4 (DB Admin) Part A GDBA – AL

FDM: Fundamentals in DBMS
EDP: Enterprise DB Processing
GDBA: General DB Admin
DMR: Data Manipulation and Retrieval
PDBD: Physical DB Design
DBAT: DB Application Tuning
DBE: DB Environment
DS: Data storage
LI, L2, L3 – Concept Levels
DBC: DB Control
EL – Elementary Level
IL – Intermediate Level
AL – Advanced Level

Figure 2: Chart showing competency level modules for some careers in Data Management

in incremental stages of conceptual knowledge. The structure and organization of course material is important as it prevents disorientation for a learner. A learner can see the linkages and relationships between the concepts and can proceed in an organized manner. Figure 3 shows a conceptual mapping diagram for the course in Data Management.

The differences between a discipline-based and a competency-based education must be taken into account when planning the learning environment. Once the skills and knowledge that form a competency have been developed, the amount of the skill or knowledge required to succeed must be determined by the organization and relevant stakeholders. The Performance Measurement and Feedback Systems, besides ensuring an effective alignment of a programs objectives and the actual industry requirements, must monitor the effective teaching and learning process towards the achievement of the predetermined course objectives. Figure1 captures the envisaged Life Cycle of the Teaching – Learning process in the competency based curriculum framework.

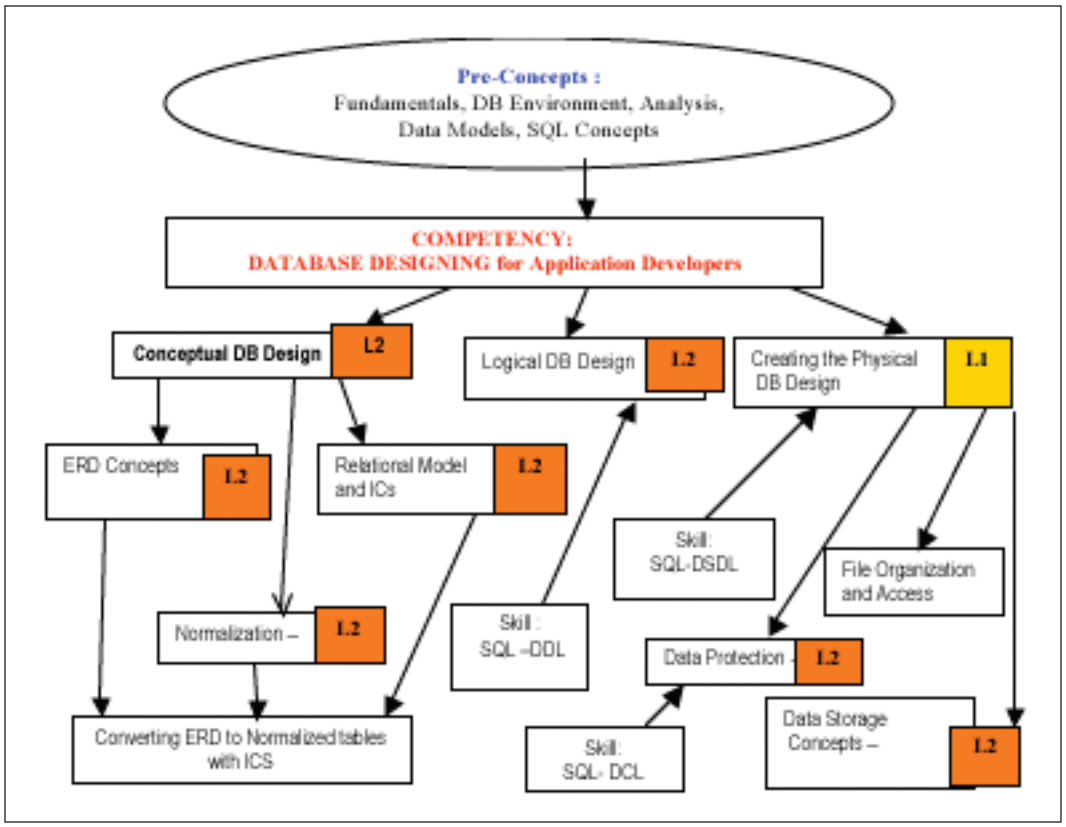


Figure 3: Diagram displaying conceptual requirements for a competency

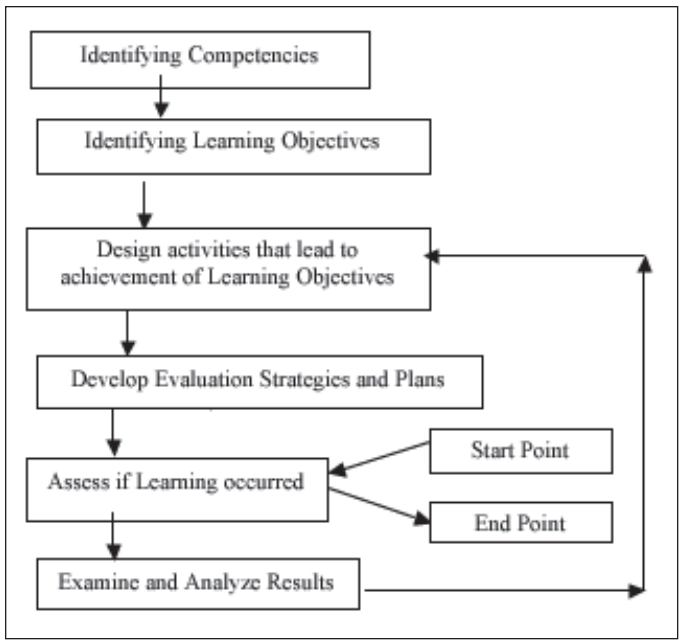


Figure 4: Life cycle of Teaching a Competency

* * * * *

5.0 IMPLEMENTING THE STRATEGY

The Masters in Computer Application (MCA) Degree Program at Goa University, India, offers a course on Database Management Systems in the third semester of its structure. The main objective of this course is that a student should be able to evaluate a business situation and build the database application in an RDBMS. Further, being a First Level Program where the candidates that offer this course come from multiple disciplines of study, the course is not targeted to the Advanced or DBAs level but focuses on an Intermediate Level (Audience Level I in Figure2). The core competencies identified were:

1. Analyzing Client Requirements
2. DataBase Designing
3. Creating and Deploying an application on a 2-tiered Architectural Platform
4. Creating Appropriate Documentation Artifacts
5. Transaction Management
6. Security Management
7. SQL (DDL and DML) - including creation of Domains, ICs, Triggers and Stored Procedures for the Application.

In the years prior to 2009, the course material was covered in a traditional method where the learning material and the flow followed standard textbooks. In the year 2009, the faculty conducting

A Strategy, Implementation and Results of a Flexible Competency Based Curriculum

continued

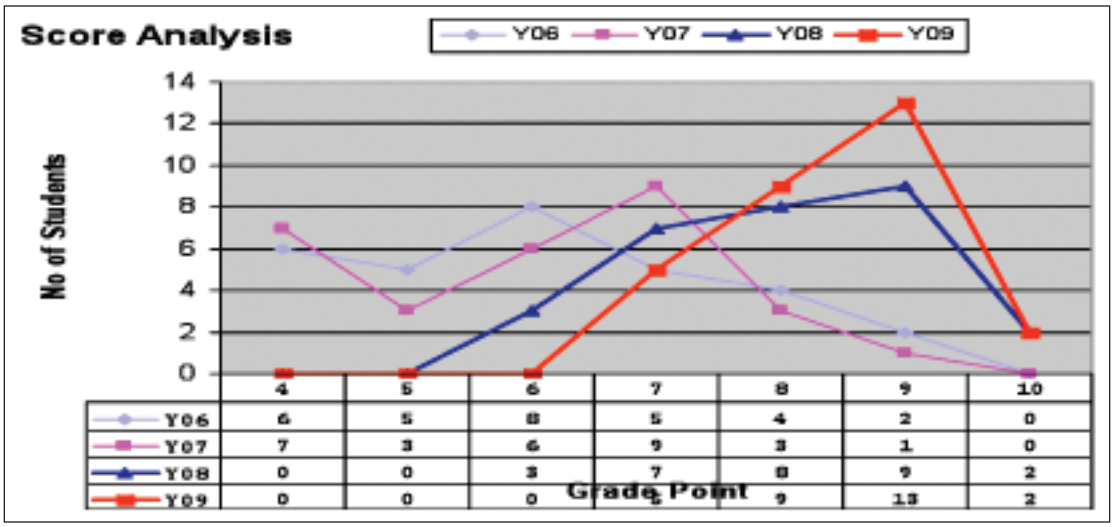


Figure 5: Chart showing scoring patters from 2006 – 2009

the course re-oriented the structure to conform to the competencies and learning outcomes as illustrated in this paper. The learners were given the conceptual mapping diagram and could thus trace the sub concepts and pre-requisites they had acquired and those that needed strengthening. The students after having undergone the course in DBMS, and having been continuously accessed on the competency areas cited above at the different levels of Blooms Taxonomy, were asked to gauge the amount of learning that took place. Students were evaluated using methods that included continuous assessments, assignments, practical work, presentations and peer-group reflective evaluations. They were split into teams and had to develop an application for existing customers with scheduled deadlines, and were required to create appropriate documentation at all phases of the Application Development Life Cycle.

After the completion of the competency, they were required to give a feedback on a scale (gradation of 0 to 4 as discussed earlier) that measured the difference in the amount of knowledge garnered before and after the competency. The students could easily identify with the scales and categorized themselves appropriately. Not surprisingly, the scales they gave themselves conformed to the grades allotted to them by the faculty. This was the first time the course was taught considering the competencies (and their pre requisites) involved and not in an order formulated by the authors of the prescribed textbooks. Activities and formal lecture sessions were targeted to acquiring a particular competency, resulting in a focused learning environment. This resulted in producing students with defined learning experiences and outcomes and a means of identifying their strengths in the course.

At the end of the semester, the students underwent a traditional summative assessment and were graded on a scale of 4 (lowest) to 10 (highest). This method of teaching in the year 2009 resulted in a better performance as can be seen from Figure 5.

The above chart is an indicator of the fact that from the year the competency based approach to teaching was considered, there was an increased and relatively uniform amount of learning. While teaching a competency, the delivery of the instructional material

TABLE 1: RELEVANT STATISTICAL INFORMATION FOR 2006-2009

Year	Average Grade	Average Deviation of Grades
2006	6.10	1.17
2007	6.03	1.21
2008	7.31	1.31
2009	8.41	0.74

and the activities are focused towards a particular learning outcome. This seems to help even the weaker students to learn more effectively as they now have smaller, tangible and thus more achievable goals. This can be seen from the sharp decrease in the Average Deviation of the Grades. Further, there is a substantial increase in the number of students scoring the higher scale point 9.

* * * * *

6.0 CONCLUSION

To accomplish the goal of education – which is to provide quality education to professionals - it is critical to have a curriculum design framework that reflects the current competency standards of the field. Industry and alumnus, who are also stakeholders in the educational system, need to be involved. The identification of the core competencies in curriculum design will help to foster relationships between industry and academia.

When the course was conducted in the earlier years, students were taught in the order formulated in the prescribed syllabus built on a prescribed textbook. This resulted in producing students with packages of knowledge, but not well defined and identifiable competencies. Students were not able to participate in their own learning process because they were unable to envision performance goals explicitly. Further, during their campus placements they were unable to identify concrete competencies that they had imbibed in their course.

Assessment efforts should not only determine whether students are acquiring the specified competencies but should enable students to visualize the desired level of performance and provide feedback for improvement. An ideal scenario would involve a mechanism for students to upgrade themselves in the competencies they failed to achieve.

The paper presents a high level framework for developing curriculum for professional courses. The forthcoming work will be on defining finer grained concepts mapped to sub-competencies. There is also a need to translate learning objectives into a learning plan - describe teaching approaches and material aimed at developing each competency and assessment targets with an emphasis on knowledge application. **Ir**

REFERENCES

[1] Armarego J.,"Deconstructing Students' Attitude to Learning: A Case Study in IT Education Presented at CSIT: Computer Science & IT Education Conference Mauritius Nov 16-18, 2007.

[2] Baloh Peter, Damij Talib, and Vrecar Peter,Faculty of Economics, University of Ljubljana, Slovenia, "Marketable, Unique and Experiential IT-Skills Education for Business Students", Issues in Informing Science and Information Technology Volume 3, 2006.

[3] Bloom B.S., Hastings J.T., Madaus G.F., Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook 1, Cognitive Domain. New York, McCay, 1956.

[4] Burrill George C, "Competency based curriculum design: An experimental model for social service workers", Alternative Higher Education (1977) 1:132-138, March 01, 1977.

[5] Fretwell D H., Lewis MV., D A, May 29, 2001,World Bank, "A Framework for defining and assessing occupational and training standards in developing countries".

[6] Garpure Prachi , M Sasikumar, Suresh Dhamapurkar, S P Mudur, "Methodology for developing courseware on on-line learning" , Working Paper , Vidyaakash Project ,NCST ,Mumbai, 2001.

[7] Gogone J ,Davis G,Valacich J, Topi H, Feinstein D, Longnecker H ,IS:2002, "Model Curriculum and Guidelines for Undergraduate programs in Information Systems", IS: 2002.

[8] Johnson D.W "Competency Based Educational Program Effectiveness Assessment "Journal of Information Systems Education, 2000, Vol 11 No 3 -4.

[9] McDaniel Elizabeth, Brenda Roth, and Michael Miller, National Defense University, Washington, DC, USA, "Concept Mapping as a Tool for Curriculum Design", Issues in Informing Science and Information Technology 2005.

[10] Morello D., "The future of competency Centers: An outward focus", Gartner Research Notes, 2002.

[11] Sudsombon Weerayute, Anmamatarkul Anusuit, "Competency Based Curriculum Development on Automotive Technology Subjects For Mechanical Technology Education", The 5th International Conference on Developing Real-Life Learning Experiences: Education Reform through educational Standards, ERES 2007.

[12] Suraka S., "What subjects and skills are important for Software Developers", Communications of the ACM, 2007, Vol 50, Number 1.

[13] Van der Sanden J.M.M., Bruijn E., Mulder R.H., "Investigating Competence Based VET in the Netherlands : background and pitfalls", ECER, Sept 2008, Germany.

[14] Van Lengen Craig A., "CIS Curriculum Development Post-Dot-com", Information Systems Education Journal, Vol 1 No 7, 2003.

[15] Williamson A., Wairua Consulting Limited " Partnering with Industry to Improve Educational Outcomes in Computing and IT " Association for Computing Machinery New Zealand Bulletin ,July 2006 Issue #3.

YMA PINTO
Dept of Computer Science and Technology
Goa University
Taleigao Plateau, Goa, India, 403206
ymapinto@gmail.com

Categories and Subject Descriptors: K.3.2 [Computers and Education]: Computer and Information Science Education—Curriculum; Computer Science Education.
General Terms: Performance, Experimentation.
Keywords: curriculum design, competency, Data Management Systems, conceptual mapping.

DOI: 10.1145/1805724.1805739