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A Generic Curriculum Model for Computing Degree Programs

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Abstract

The current literature shows the existing curriculum models are unable to meet the needs of the today?s dynamic complex education as the society is more open, diverse, multidimensional, fluid and more problematical. A generic curriculum model is proposed for all types of computer degree programs. The proposed model defines five meta-processes, a flexible structure for hidden and formal curriculum, and innovative ideas for branding and capstone project. Taking a futuristic approach and keeping an eye on the emerging needs of today?s knowledge driven society, the proposed model aims to transform students into valuable plug-n-play knowledge workers equipped with up-to-date knowledge, marketable skills, valuable competencies, unique expertise, globally compatible dispositions and culturally and professionally acceptable values. Through introducing competencies, expertise and dispositions among threshold standards we have given a new starting point for curriculum experts to extend the virtual boundaries of teaching-learning environment from classrooms to work-place environments. The proposed model not only meets the existing needs of the core computing disciplines but also accommodate the implications of newly emerging disciplines. Its flexible structure allows both institutions and faculty to decorate it according to their requirements.

Index terms— Computing Curriculum, Computing Model Curriculum, Dispositions in Computing, Hidden Curriculum in Computing, Global Education in Computing, Flexible C

Introduction urriculum development has always been a topic of great concern among academia. In literature many curriculum models have been proposed to increase academic rigor and students' academic achievements (Tyler, 1949;Taba, 1962;Wheeler, 1967;Walker, 1971;Eisner, 1991;Biggs, 1996 These curricula mainly identify a core body of knowledge (CBOK), curriculum structure, implementation strategies, threshold standards, and professional practices. The threshold standards are defined considering only knowledge & skills. In some curricula Bloom's (1956) taxonomy is used to define these standards whereas some curricula have used very generic statements like "[graduates should] Demonstrate a requisite understanding of the main body of knowledge and theories of computer science" (ACM/IEEE, 2001, p66). Such generic statements cannot define the level of knowledge and skills. The CBOK, curriculum structure and implementation strategies are different in each discipline. As a common practice new knowledge areas have been added in the CBOK as new concepts emerge which increasing the size of the CBOK. Professional practices are considered as a discrete knowledge area to be taught separately.

Although, no specific approach has been indicated, these curricula appear to be developed according to Tyler's (1949) product model. Dennis, (2002) comments Tyler's model is highly structured and systematic. It gives a complete paradigm with all the major considerations. It is a closed system, easy to follow and being considered very effective for public education. The model follows the rationality ruleseverything is predictable, ordered, measurable, objective and scientific. It is performance based, behaviourist and outcome focused. The standards can be set and the learning objectives can be measure. (Dennis, 2002) Tyler's (1949) model is also known as "product" model and greatly influenced curriculum development in America (O'Neill, 2010). The product model has been considered valuable when developing and communicating outcomes to the student population and has moved emphasis away from lists of content. However, literature suggests that in using this model care should be taken not to be overly prescriptive when writing learning outcomes (Hussey & Smith, 2008). Doll (1993) criticizes Tyler's model for its linear ordering of the sequence: pre-set goals, selection, and direction of experiences, evaluation and its dichotomous separation of ends from means and the instrumentalist or functionalist view of the nature of education. Knight (2001) argues that writing program and/or module learning outcomes first is less effective than to first considering the aim of teaching/learning activities. Doll (1993) argues that Taylar's model is inconsistent with today's dynamic & complex educational requirements as the society is more open and diverse, multidimensional, fluid and more problematical.

We believe both Doll & Knight's ideas are equally applicable in the computing domain which is very dynamic and rapidly expanding in nature. The multi-dimensional usage of computing in conventional disciplines is giving birth to new disciplines. This dynamicity of the computing domain and the emerging needs of the rapidly changing society demand a generic curriculum development model which could be equally effective for the degree programs of both existing and newly emerging computing disciplines (ACM/IEEE-CS, 2012). To address this research problem, this paper has proposed a generic curriculum development model for computing degree programs. The structure of the paper is as follow. A historical review of computing discipline is given in Sec. 2. Various curriculum development models are discussed in Sec. 3. The proposed curriculum development model for computing degree programs is presented in Sec. 4. The concluding discussion and recommendations are given in the last section.

1 II.

2 A Historical Perspective of Computing Disciplines

In early days, 'Computer Science' was used as a common term for computing. With the passage of time, the nature of basic principles, methods, techniques and concepts evolves. Even some new concepts refuted the old ones. For example, Hilbert's principle that formal mathematical theorems are provable by logical inference was questioned by Kurt Godel (1931) and Alonzo Church & Alan Turing (1936) that logic cannot completely prove all mathematical theorems. Similarly, many contradictory views of computing opened up new horizons for computing like the mathematical worldview (Davis, 1958) vs the interactive worldview (Goldin & Wegner, 2008), algorithmic programming (Hopcroft & Ullman, 1969) vs contemporary programming (Rice & Rice, 1969), etc. Before 1990's, computing was limited to three disciplines -Computer Science (CS), Computer Engineering (CE), and Information Systems (ISs). By 1990s, the global community realized that the field of computing had grown in many dimensions. Different academic institutions started offering different degree programs in Software Engineering (SE). Consequently, the discipline of SE was added in the computing domain.

Most of us are witnessed the inventions of personal computers revolutionized the conventional concepts of calculation and changed the way data was stored, retrieved and controlled. Computers became essential tools at every level and networked computer systems became the information backbone of organizations (Kotkin, 2000). It also expedited the pace of inventions (Thomson, 2007) resulting many innovations in communication and computation technologies which brought a paradigm shift in the business world -from data processing to information processing; converting industrial society into an information society **??**Cohen, 2009). While this paradigm shift improved productivity, it also brought new challenges regarding the development, operation, maintenance, and up-gradation of organizational information management infrastructure **??**Samuelson, 1995).

By the end of 1990s, once again the academia realized that the existing computing degree programs were not producing graduates who had the right mix of knowledge and skills to meet organizational challenges (Lunt, et. al., 2005). Consequently, universities developed new degree programs in Information Technology (IT) to fill this crucial void (Denning, 2001); Hence IT was introduced as a new family member of computing disciplines (Lunt, et. al., 2005). The key characteristics of these five distinct but overlapping disciplines are discussed in Computing Curricula 2005 (ACM/IEEE-CS, 2005).

In recent years many significant developments have been made and many new concepts have been introduced like "Computational Lens" (Karp, 2011) which articulates a new relationship between computer science and other sciences, "ternary computing" dealing with computing for the masses **??**Li, 2010), "e-Science" Managing massive experimental data and collaborating via the Net, "Computational Thinking" (Wing, 2008), Cloud Computing (Li & Zhang, 2009), etc. Computing has also widespread usage ranging from regulation of protein production & metabolism, phase transitions in physical systems, strategic behavior of companies, regulating the mechanics of learning, managing the Web-based social networks, etc. In parallel, the integration of computing in other disciplines introduces new disciplines like "computational-x" (e.g., computational mathematics, computational physics, computational finance, etc.) and "x-informatics" (e.g., bio-informatics, dental-informatics, clinical-informatics, etc.). This dynamic nature of computing has made the curriculum development for degree programs a challenging task (ACM/IEEE, 2013).

3 III.

4 Curriculum development models

Although the development of an effective curriculum has always been a topic of great concern in school education (Tyler, 1949;Taba, 1962;Wheeler, 1967; ??alker,1971), many serious concerns from higher(D D D D) B 2012

Year education made curriculum development an important research agenda for the higher education community. These concerns include lack of coherence, practicality, accessibility, quality, integrity, and overburdened ??HEC, 2012). In parallel, the business and industry leaders' concerns of inadequate skills of graduates (UNESCO, 2012) and citizens' concerns about graduates' disengagement from civic life (Kerr & Blenkinsop, 2005) further revels the shortcomings of the existing curriculum. Many deliberate attempts have been made to develop a curriculum model to increase academic rigor, sharpen students' critical thinking and analytical reasoning, and expose them to richer subject matter. Consequently, three main research strides emerge: a) Instructional methods In addition to conventional lectures and classroom discussions, many innovative instructional methods emerge in higher education like active learning, experiential learning, inquiry based learning, discovery based learning, problem-based learning, project-based learning; collaborative and cooperative learning, understanding by design, etc.

5 b) Evaluation & assessment

In addition to descriptive and multiple choice, new evaluation methods have been developed to promote Bloom's higher-order thinking and other competencies required in the employment market. New methods include self-assessments, students' portfolio, open book test, case studies analysis, group projects, prototyping, technology-based evaluation, etc.

6 c) Curriculum coherence & integration

The latest research brings many reforms in curriculum structure like integrating general education across the curriculum, integrating the disparate elements of students' learning experiences, shifting from curriculum objectives to attaining competencies, etc.

In addition to these aspects, some individual's work created a noticeable impact on curriculum theory. For example, in response to the increasing popularity of constructivist learning theory (Bruner, Goodnow, & Austin, 1956) and instructional design ??Seels & Glasgow,1990) in higher educational practice, Biggs' (1996) put forwards a notion of constructive alignment. He adopted the idea of instructional design alignment from Cohen's (1987) who replaces learning with attainment (Biggs, 2002). Instructional alignment demands a precise match between what is intended to be taught, what is intended to be evaluated and what is intended to be learnt (Talbot, 2004). Whereas, constructive alignment asks for a shift from behaviorists' pedagogy to constructivist's pedagogy through stating the curriculum objectives in terms of the level of understanding required of a student than just listing the topics to be covered. Eisner (1991) model combines behavioral principles with aesthetic components to form a curriculum. His model is based on five core elements: intentional, structural, curriculum, pedagogical, and evaluative.

Over the last few years, new curriculum models in higher education have been developed to accommodate new means of delivery, access and storage of information and to incorporate more flexibility into the existing curriculum to provide better access to a wider range of students' body ??Tinkler, et.al (Bruner, 1996), transformational curriculum (Parker, 2003), Project Based Learning, Standards Based Learning, Curriculum Mapping (Jacobs, 1997), Integrated Course Design (Fink, 2003), etc.

In this section we have discussed various curriculum development models. The literature reveals that no one model is ideal and no one model may suit to all disciplines. Natural sciences are different from the social sciences and require a different curriculum development approach. Computing is a rapidly evolving discipline and requires a more fluid & flexible model than Tyler's product model. Ornstein and Hunkins (2009) suggest that although curriculum development models are technically useful, they often overlook the human aspect such as the personal attitudes, feelings, values involved in curriculum making. In the next section we have proposed a process oriented generic curriculum development model for computing degree programs both in core computing disciplines and newly emerging fields such as "computational-x" and "xinformatics".

IV.

7 The Proposed Curriculum Development Model for Computing Degree Program

In the proposed model curriculum development is defined as "a meta-process focuses on the constructing of a wide range of new processes or improving the existing ones to improve and support the curriculum development, execution and auditing activities to increase academic rigor, sharpen students' critical thinking and analytical reasoning, and expose them to richer subject matter."

The model defines the key processes involve in developing an effective curriculum for producing wellrounded computing graduates equipped with professional competencies ready to work in a more holistic way than simply demonstrating technical skills. The model, shown in Figure1, has adopted a recursive approach for curriculum development and its implementation. Different processes are responsible of performing different tasks. Unfortunately, due to space limitations not all the related aspects could be discussed here. Only the key processes of the proposed model are briefed here.

8 a) Identification of Standards

This process is aimed to identify curriculum's objectives & students' learning standards aiming at the ”future” trends, national needs, and the society's expectations about students' characteristics. Focusing on ”future” is one of the key aspects differentiating this model from the existing ones. Also, the threshold standards are based on following six parameters; not only just knowledge and skills: i.

9 Knowledge

Theoretical learning of concepts and principles regarding a particular subject(s).

ii.

10 Skills

Capability of using learnt knowledge and applying it according to the context.

iii.

11 Competencies

An ability to do something satisfactory-not necessarily outstandingly or even well, but rather to a minimum level of acceptable performance. Introducing common core in all degree programs may address many issues related to degree accreditation and quality education.

Hidden Curriculum is the second important component of the proposed model. It deals with elements like socialization, professional practices, desired dispositions, etc., which are embedded in the curriculum, the university and classroom life and is imparted to students through daily routines, curricular contents and social relationships, but is not a part of the formal curricular content.

12 d) Curriculum Execution

This process ensures the smooth delivery of the curriculum. It has three sub-processes: i) Managing external factors like contemporary life, technology, knowledge, ideology, economics, pressure groups, government policies, legal constrains, etc. ii) Managing internal factors like teachers, students, school environment, institutional policies and strategies, etc., and iii) Quality assurance procedure.

13 e) Curriculum Auditing

It involves the auditing of the curriculum taking into account aspects like, effectiveness, relevancy, acceptability, matching with national standards and accreditation recommendations, etc.

For meeting the emerging need of the dynamic nature of computing domain and the changing trends of the employment market, all processes are linked through a bi-directional inter-processes communication channel called fine-tuning and feedback channels. Both people and processes can generate fine-tuning and feedback messages to make positive changes in the curriculum. Similarly, all the processes and subprocesses can be tuned-up according to the emerging trends and needs of the market and society.

V.

14 Conclusion & recommendations

Although computing has become a mature discipline, high paces of knowledge exploration, invention of new technologies, and the emergence of new disciplines have introduced new challenges to curriculum development for computing degree programs. Presently, Tyler's (1949) product model is commonly followed in the development of curricula for computing degree programs. Many researchers have objected that product model fails to meet the needs of the today's dynamic & complex education as the society is more open and diverse, multidimensional, fluid and more problematical.

We live in the era of knowledge economies in which science and technology bonding has become stronger than ever before, continuing education and lifelong learning have got unprecedented importance, investment in intangible assets has become more valuable than investments in fixed capital, the relationship between knowledge, technology and innovation has become more important for economic growth and competitiveness (Utz, 2006). Although such activities all over the world are increasingly becoming knowledge oriented, but the degree of incorporation of knowledge and technology into economic activity is now so great that knowledge & technology have been recognized as the key drivers of productivity and economic growth (Kogut & Zander, 1992;Nonaka & Takeuchi, 1995;Choo & Bontis, 2002; **??**ítek & Klímová, 2011). The basic economic resource -the means of production -is no longer capital, neither natural resources, nor labor. It is and will be knowledge & the knowledge workers who possess high levels of education and/or expertise in a particular area, and who use their cognitive skills to engage in complex problem solving. Such knowledge workers will be the assets of the organization (Drucker, 2006). **??**rucker (2006, p. 165) says, "It is generally accepted that the knowledge workers' expertise in their role is the starting point for enhancing both their individual and their contribution to the organization's productivity, quality and performance. If knowledge workers are to continue contributing to organizations and the economy at large, their knowledge must remain up-to-date." Davenport (2005) sees knowledge workers as people with high degrees of expertise, education, or experience and they are mainly involved in the creation, distribution, or application of knowledge.

Hence, transforming students into valuable knowledge workers able to work in future work places is one of the key purposes of the proposed curriculum development model. We believe the increased competition of the business world cannot just rely on graduates' knowledge and skills.

Graduates' competencies, expertise and disposition will play a central role in gaining competitive edge in today's competitive world. Therefore the proposed model's learning standards are aiming to produce knowledge workers equipped with: up-to-date knowledge; marketable skills; valuable competencies; unique expertise; globally compatible dispositions; and culturally and professionally acceptable values Usually, standards are set according to existing practices. Time has come to adopt a proactive approach and standards should be set according to the future needs of both society and organizations. Through introducing competencies, expertise and dispositions among threshold standards we have given a new starting point for curriculum experts to extend the virtual boundaries of teaching-learning environment from classrooms to workplace environments.

Usually, competencies and expertise are associated with experience. Time has come to rethink this concept. Today organizations need plug-n-play work force. Among a skilled programmer, a competent programmer, and an expert programmer, the organization will naturally go after an expert programmer.

Similarly, being a programmer (disposition) is more valuable than having a programming skill or knowledge. Therefore, curriculum contents, teaching-learning activities and assessment and evaluation methodologies should be in line with market demands. Instructors need to move forward from pure academic contents' delivery to sharing of market oriented practical knowledge.

The model shown in Figure **??** depicts the key functions of the knowledge domains included in the curriculum. Time has come to realize the emerging challenges of forthcoming expansion of computing discipline. In place of adopting the conventional core curriculum approach the proposed model's flexible structure has unleashed the computing giant to demonstrate its potential in today's interdisciplinary world.

The proposed model has a small core encompassing common areas of computing. This approach allows institutions to cater the needs of different computing degree programs and to offer the body of knowledge which is in line with the true spirit of the discipline and needs of the employment market.

It may be argued that the proposed model has eliminated the conventional core area like data structure and algorithms, data-communication, digital logic design and computer organization, etc. We believe these subjects have different standpoints in different disciplines. For example, low level programming is more useful for CE students as compare to IS students. To develop an appropriate mindset students' need to study appropriate contents and perform associated activities. These aspects could be covered under the category of 'Domain Specific Elective Courses'. Similarly, courses like discreet structures, data-communication, digital logic design and computer organization should be offered under 'Foundation Elective Courses'. Science, Mathematics, etc. should be covered under 'Interdisciplinary Elective Course'.

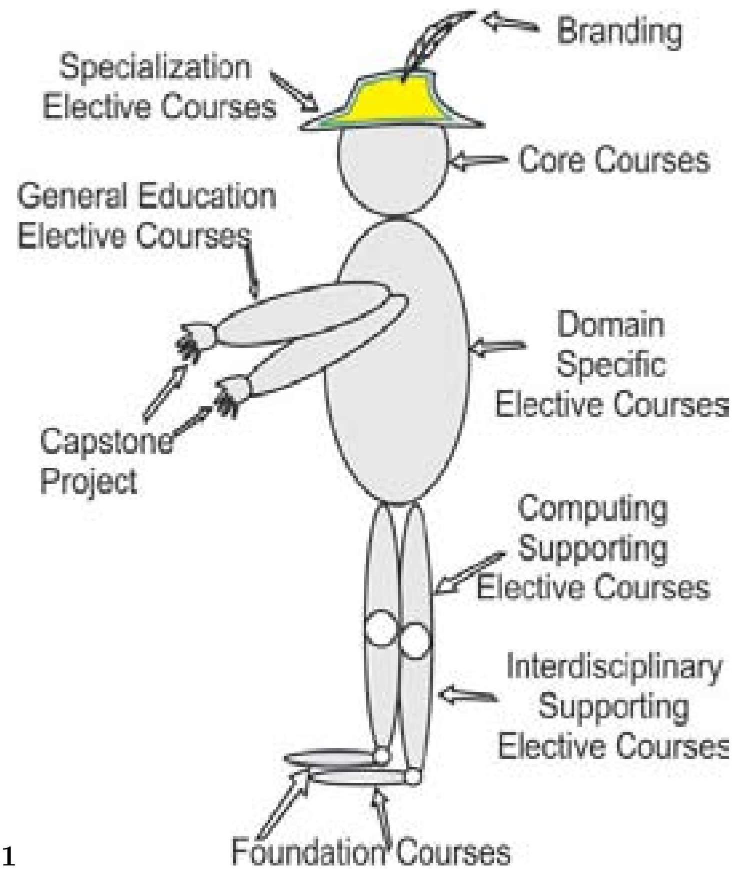
Courses like Philosophy, sociology, the comparative study of religions, etc. should be taught under 'General Education Electives'.

The importance of Capstone project has already been realized in existing curricula. However, the proposed model has advocate for a composite approach towards the completion of the Capstone project. The students may work on smaller projects which can be integrated into a bigger project. Also, students can be encouraged to work in a collaborative environment. In this regard computing institutions can establish an online collaborative working environment through which students from different institutions can work together on a common project. These way students will learn about the current trend of distributed product development, outsourcing, etc. It will also allow institutions to share the available resources (structural, human, and technological) up to their maximum capacity.

Hidden Curriculum is an important aspect of the proposed model. Jackson(1968), who coined the term, argues that features like norms, values, dispositions, belief systems and social and behavioral expectations have little to do with educational goals, but are essential for students' satisfactory progression (Margolis, 2001). The proposed model suggests that life skills including desired dispositions, soft skills, public speaking, critical thinking & reasoning, ICT literacy, personal attributes, entrepreneurship, attitude towards lifelong learning, professional practices and other social skills should not be considered discrete items and should be threaded into the entire fabric of the curriculum and taught as a hidden curriculum through various elements of the education system. These elements include classrooms' social structure, teachers' exercise of authority, the rules governing teacher-student' relationship, teaching learning activities, and socio-cultural and structural barriers in the institution.

'Branding' is another important aspect addressed in the proposed model. Branding in higher education is a current topic among the academic community (Toma, 2005;Brunzel, 2007;Temple, 2006). Internationalization of higher education has further raised the importance of branding. To that end, Toma (2005) suggest that "branding" an institution in accordance with its cultural values and norms can help a university differentiate itself in an already crowded and competitive marketplace, whether that competition is for students, donors or public support. Working on these lines the proposed model allows institutions to develop their own brands through integrating branding features in the hidden curriculum or integrating special knowledge areas in the formal curriculum. The structure of the proposed model provides room for institutions to decorate it according to their needs. However, it is radically important that to have coherency and consistency in curriculum institutions & faculty also need to demonstrate it. If they curtail these aspects, then no matter who ever are teaching, the set target would easily be achieved.

Figure 1:



1

Figure 2: Figure 1 :

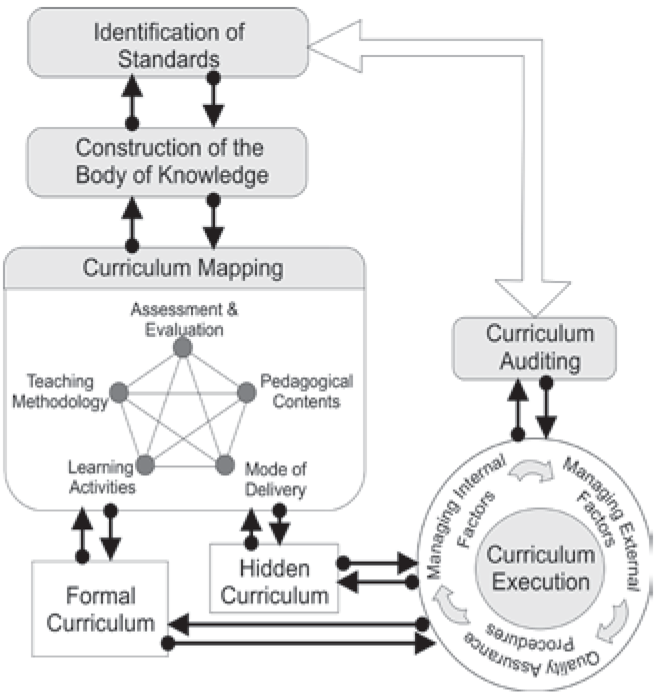


Figure 3:

Figure 4:

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