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Rethinking of Computing Curricula in Higher Education in Pakistan

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Abstract: Developing & implementing appropriate curricula is a paramount challenge in computing education. To meet this challenge, educators from all over the world are updatingcurriculum ona regular basis.Recently, the Higher Education Commission of Pakistan has revised the existing curricula of degree programsto standardize computing education in Pakistan. Taking a content analysis approach the studyhas pointed out some shortcomings of the revised curricula.The study recommends that the teaching of over-crowded course contents must be discouraged as it promotes rote learning and inhibits creativity and innovation. Curriculum development processes must be followed to develop an effective curriculum. Also, the curriculum must enrich students' experiences, thoughts, beliefs, assumptions, and attitudes in their field of study to develop special characteristics and mindset. The recommendations made in this study may help the concerned authorities to take measures to improve the quality and standards of the computing curricula in Pakistan.

Keyword:Computing Curricula, ComputingCurriculum Development, Computing Higher Education**,** Computer Science Curriculum,Information Technology Curriculum, Software Engineering Curriculum

I. INTRODUCTION

Computing is an interdisciplinary discipline that crosses the boundaries between mathematics, science, engineering, business and social sciences. It consists of multiple disciplines including computer science, software engineering, computer engineering, information technology, and information systems [1]. These disciplines are inter-related but are quite different in nature whichpropels the international community to devise model curricula for computing degree programs. Since the publication of the preliminary version of the recommendations for Computer Science curriculum [2] educators and professionals all over the world are striving to formalize the fundamental principles that distinguish the goals and methods of computing from those of other related disciplines. Recently, the international community has put forward a draft version of Computer Science Curricula 2013 [3] which has redefined knowledge units and has provided guidelines on curricular structure in a variety of institutional contexts.

Curriculum is acentral pillar of an education system. Prof. Dr. Altaf Ali G. Shaikh [1] states, "Curriculum of a subject is said to be the throbbing pulse of a nation. By looking at the curriculum, one can judge the state of intellectual development and the state of progress of the nation."[4;p.4].It is an important proviso,yettoensuresocio-economic progress and to maintain the highest standardsof learning for all students, curriculum development needs a clear vision[5], teachers' involvement, commitment and innovativeness [6],in-depth domain knowledge, comprehension of curriculum development methodologies[7]and understanding of the actual and developmental needs of the education system&society at large [8].

Designingan appropriate curriculum is a key to success in today's educational world[9]. Yet,designingan appropriatecurriculum andkeeping it up-to-date is achallengingtask as [4; p. 4] states,"The world has turned into a global village; new ideas and information are pouring in like a stream. It is, therefore, imperative to update our curricula regularly by introducing the recent developments in the relevant fields of knowledge."

In this paper, after giving an overview of computing education in Pakistan and research methodology of the study, a content analysis of the HEC revised computing curricula [4]is presentedwith a special focus on BS programs in computer science, software engineering, and information technology. Since the publication of HEC's revised curricula, it is the first attempt to analyze its contents. The concluding remarks and recommendations for making computing curriculum more effective are presented in the last section.

II. COMPUTING DISCIPLINE IN PAKISTAN

In Pakistan, at university level computer education can be traced back to late 70's when a department of computer science was established at Quaid-e-Azam University, Islamabad. Presently, 74 public and 62 private universities including their affiliated colleges are offering degree programs in various computing disciplines. To ensure the quality of education students receive in universities and institutions, the Higher Education Commission (HEC) has setup an accreditation authority: National Computing Education Accreditation Council (NCEAC). The accreditation council periodically evaluates, scrutinizes and monitors the standards followed in different Universities, Degree Awarding Institutions and their affiliated colleges offering computing degree programs.

In addition, realizing the need of standardization, HEC as a part of its constitutional responsibility, has constituted four committees, as stated in [4], involving the respective expert faculty members both from public and private sectors throughout the country. All these committees worked independently in their respective domains through extensive interaction and consensus of national and international experts in the field and revise the existing curriculum after every three year. Recently, in 2009, the curriculum revision committee has published the revised curriculafor BS, MS and PhD programs. The revised curricula [4] have been circulated nationwide for implementation.

III. RESEARCH METHODOLOGY

This desktop study has been carried out using content analysis methodology. Content analysis is a qualitative research methodology entails the systematic examination of forms of communication to document patterns objectively [10]. This methodology allows the study to identify the short comings of the existing curriculum. For analysis purpose, the study utilizes published research in the form of books, research papers, official reports and guidelines, library material and material from the Internet with an aim to get the insight and perspectives that have been brought by various international bodies regarding computing discipline. Interviews and discussions were also conducted with members from key interest groups such as university teachers, head of the computing departments and professionals from software industry. The aim of the interviews & discussions was to collect participants' feedback and concerns about the revised curricula that might be need to be addressed by the study.

IV. ANALYSIS OF THE REVISED CURRICULA OF CS, SE, AND IT

On behalf of HEC, the Joint National Curriculum Revision Committee for CS, SE and IT revised the existing computing curricula with a keyobjectiveto develop a model to unify all the curricula and create a systemic structure to maintain consistency of certain level in all the degree programs[4;p. 7]. In 2009, the revised curricula were circulated nationwide for implementation. A critically analysis of BS programs of the revised curricula is presentedin this section.

The details of common areasfor all BS Programs - Computing, Supporting Area, General Education& University Elective Courses are listed in Table I.

Table I: Structure of BS Programs in CS, SE, and IT (Source: [4; p. 16]

Name of Program	**CS**		**SE**		**IT**	
Category	**Credit Hours**		**Credit Hours**		**Credit Hours**	
Computing Courses		70		70		70
Core Courses	43		43		43	
Supporting Areas	12		12		12	
General Education	15		15		15	
Software Engineering Courses		48		48		48
CS Core Courses	18		18		18	
CS Electives Courses	21		21		21	
CS Supporting Areas Courses *(Electives)*	9		9		9	
University Electives		12		12		12
Total Credit Hours		130		130		130

A comparison of Common Computing-Core courses among General Recommendations and CS, SE, and IT curricula shown in Table II.

Table II: Common Computing-Core Courses in BS Programs

General Recommendation		**Computer Science**		**Software Engineering**		**Information Technology**	
Computing - Core Courses (43 Credit Hours) (Source: [4]; p.17)		Computing - Core Courses (34 Credit Hours) (Source: [4]; p.37)		Computing Core (37 Credit Hours) (Source: [4]; p. 80)		Computing — Core Courses (37 Credits Hours) (Source: [4]; p. 120)	
Introduction to Computing	4 (3-3)	Programming Fundamentals	3 (2, 1)	Introduction to Computing	4 (3-3)	Programming Fundamentals	4 (3-1)
Programming Fundamentals	4 (3-3)	Object Oriented Programming	3 (2, 1)	Programming Fundamentals	4 (3-3)	Object Oriented Paradigm	3 (2-1)
Object Oriented Programming	3 (3-0)	Data Structure and Algorithms	3 (2, 1)	Object Oriented Programming	3 (3-0)	Discrete Structures	3 (3-0)
Discrete Structures	3 (3-0)	Digital Logic Design	3 (2, 1)	Discrete Structures	3 (3-0)	Data Structure and Algorithms	3 (2-1)
Data Structure and Algorithms	3 (3-0)	Operating Systems	3 (2, 1)	Data Structure and Algorithms	3 (3-0)	Digital Logic Design	3 (2-1)
Digital Logic and Design	3 (3-0)	Database Systems	3 (2, 1)	Digital Logic and Design	3 (3-0)	Operating Systems	3 (2-1)
Operating Systems	4 (3-3)	Introduction to Software Development	3 (3, 0)	Operating Systems	4 (3-3)	Introduction to Database Systems	3 (2-1)
Introduction to Database Systems	4 (3-3)	Computer Communications and Networks	3 (2, 1)	Introduction to Database Systems	4 (3-3)	Introduction to Software Development	3 (3-0)
Introduction to Software Engineering	3 (3-0)	Final year Project	6	Introduction to Software Engineering	3 (3-0)	Computer Communications and Networks	3 (2-1)
Computer Communications and Networks	3 (3-0)	Human Computer Interaction	3 (2, 1)	Computer Communications and Networks	3 (3-0)	Human Computer Interaction	3 (3-0)
Human Computer Interaction	3 (3-0)			Human Computer Interaction	3 (3-0)	IT Capstone	6 (0-18)
Senior Design Project	6 (0-18)			Senior Design Project	6 (0-18)		

To bring consistent standards across all three curricula was thekey objective of the revision exercise. In contrast, the analysis reveals many conflicting features as listed below:

a. General Recommendations have not been followed.In general recommendationsthe Computing Core Courses are of 43 Credit Hours. Whereas,these courses are of 37 Credit Hours in both IT & SE curricula and 34 Credit Hoursin CS curriculum but the sum of the listed courses in CS curriculum is 33 Credit Hours (See Table II).
b. Inconsistency in course credit. The courses of 4 Credit Hours in general recommendations are offered as 3 Credit Hours courses in CS, IT and SE curriculum (See Table II). It is important to mention that the syllabuses of these courses are defined in the general recommendations where these courses are of 4 Credit Hours.
c. ‘Electromagnetism’ course appears in General Recommendations as a core course but it is missing in CS, SE and IT curricula. It is more alarming that the topics included in thegiven syllabus of this course provided in the general recommendations are related to ‘Electronics’ whereas the reference books are related to ‘Physics’. Also the course objectives are outrageous.
d. The Course Objectives defined in the syllabuses arenot in-line with the contents of the courses and are ambiguous.
e. The syllabuses of some courses are missing like Data Structure & Algorithms, Digital Logic & Design, etc.
f. Inconstancy in course category titles.For example,‘Supporting Area Courses’ in the general recommendations; ‘Computing-Supporting Courses’ in CScurriculum; ‘Computing Requirements-Supporting Sciences’ in SEcurriculum and ‘Computing Supporting Sciences’ in IT curriculum (See Table II).
g. In the general recommendationsEnglish-II & English-III are titled as ‘Communication Skills’ & ‘Technical and Report Writing’ respectively whereas in CS curriculum English-II is titled as ‘Technical and Report Writing’ and English-III as ‘Communication Skills’.
h. Many emerging topics define in [4] like Security, Information Assurance, Parallel and Distributed Computing etc. are missing.
i. The structure of the curricula deviate from international recommendations proposed in [4].
j. The revised curricula appear to be no more than a collection of syllabuses. It does not specify the main teaching, learning and assessment methods requiresupporting the effective delivery of course contents. Similarly, many components which are the important components of an effective curriculum are missing like evaluation strategies, courses’ pedagogy, etc.

V. CONCLUSION & RECOMMENDATIONS

The study has identified many anomalies, inaccuracies, and contradictory aspects of the revised curricula which bring itsquality open to debate. Theidentified anomalies, inaccuracies, and contradictory aspects could not be categorized as some typographical mistakes.A more professional approach is required for the development of such an important document.In addition to these aspects, in this section, we will concentrate on some pedagogical aspects related to the curricula which need attention.

Starting with the teaching of 4 Credit Hours course contents in 3 Credit Hourswhich makes the contents of the courses overcrowded. Research has shown that overcrowdedcontentscause negative impact on students’ learning, motivation and academic achievements[11].The learning process involves mental efforts. Neerincx, et. al.[12]have distinguished three load factors that have a substantial effect on mental effort: i) percentage time occupied, ii)level of information processing, and iii)task-set switching. The combination of these factors determines the cognitive load on working memory. The teaching ofovercrowded coursesoverburdensstudents’ working memory which is the central processor for learning and thinking [13]. DiCarlo[11] argues that attemptingjust to cover the overcrowded course contents limit students to simply learning facts without developing the ability to apply their knowledge to solve novel problems. It puts extra cognitive load on students [14] and makes both faculty and students overburdened [15, 16]. As a result,the students’ academic achievements get effected[17,18]. For an effective learning students need to beengaged in higher order cognitive activities which are related to the upper half of Bloom’s taxonomy [19].

Teaching is not just the delivery of contents. Teaching demandsthe development of instructional methods that efficiently use students’ limited cognitive processing capacity to stimulate their ability to apply acquired knowledge and skills to new situations [20]. Clark & Harrelson [21]explain, for learning to occur, new sensory information from the visual and auditory systems must be integrated in working memory to form a coherent idea. These ideas are then rehearsed in working memory to integrate new ideas into the existing memories (called schemas) in long-term memory. The integration of new data into existing schemas is called encoding. As all processing take place in working memory,to see the practicality of the new knowledge/skills which is going to be encoded into long-term memory, the new knowledge must be retrieved into working memory [19].This process initiates creativity which generates new schemas and helpsthe students to develop the ability to apply newly learnt knowledge to solve novel problems. However, the students need enough time to rehearse the new ideas in their working memory so that it could be encoded and integrated in long-term memory for future use. The teaching of overcrowded contents does not leave time for students to do so. Consequently, students left with no other option except rote learning. To promote students’ creativity and innovative skills, it is strongly recommended,the curriculum contents must not be overcrowded so that an effective teaching-learning processtakes place.

Although the issue of inconsistency is obvious in the revised curricula, the quality of the contents has also raised many concerns. The increasing trends of out sourcing [22] and global employment [23]demand from Pakistani graduates to develop skills which help them to compete with graduates from other international universities. They also need to learn about newlyemerging computingconcepts likeInformation Security, Information Assurance, Parallel and Distributed Computing, Social Media and

KnowledgeManagement technologies, etc. These aspects are missing from the revised curricula.

One of the key objectives of computing education is to prepare students for their professional careers in a more holistic way. In today's employment market, "soft skills" (such inter-personal communication, leadership, teamwork, etc.) and professionalism are equally important. For a successful career path, in addition to technical knowledge, students must be equipped with these skills. It is imperative for academia to understand these new challenges and devise curriculum accordingly.Recently,[3] has put forward following principles as computing curriculum development guidelines:

a. Curricula must be broad based and should provide students with the flexibility to work across many discipline& professions.
b. Curricula should be designed to prepare graduates to succeed in a rapidly changing field.
c. Curricula should provide guidance for the expected level of mastery of topics by graduates.
d. Curricula must provide realistic, adoptable recommendations that provide guidance and flexibility, allowing curricular designs that are innovative and track recent developments in the field.
e. Curricula guidelines must be relevant to a variety of institutions.
f. The size of the essential knowledge must be managed.
g. Curricula should identify the fundamental skills and knowledge that all graduates should possess.
h. Curriculashould provide the greatest flexibility in organizing topics into courses and curricula.

The rapid evolution, expansion and development of computing technologies and their applications in diversified fields have made the curriculum development a challenging task. The increasing integration of computing concepts with other disciplines has created additional challenges. These aspects have acknowledged in the recent report [3]. The report hasproposed newstructures for computing curriculum and related body of knowledge. The report has mentionedthree major causes of doing so: i) the reorganization of existing knowledge areas, ii) the development of cross-cutting knowledge areas, and iii) the creation of entirely new knowledge areas.

The new structurehas divided the body of knowledge into two groups: "core" and "elective". The core is further sub-divided into "tier-1" and "tier-2.".According to this structure, the curriculum must include all topics included in the tier-1 core and must be taught to all students. The curriculum should include all or almost all topics in the tier-2 core and ensure that all students cover the vast majority of this material. In addition, the curriculum should include the significant elective material: covering only "core" topics is insufficient for a complete curriculum.Every graduate in their respective discipline must acquire the desired skill set [3].

Yet, there is another aspect which must not be overlooked which is the development of students' mindset. Mindset provides guidelines for living and influences how individuals experience life and then interprets and createstheir own 'realities' and 'believes' whichframetheir behavior towards a specific task/field/profession [24].

It is important to note that each profession needs both a specific skill set and an appropriate mindset [24]. According to Peterson et al. [25], mindset is a level of understanding having three key components: i) the availability of a specific knowledge domain, ii) the ability to process information against this knowledge domain, and iii) the ability to monitor ones thoughts and thought processes. As discussed earlier, the distinctive characteristics of various computing discipline has already been identified by the globalcommunity. For example, and IT graduates need to have a different mindset from software engineering or computer engineering graduates. Developing an appropriate mindset of the prospective computing graduates requires a body of knowledge which enriches students' experiences, thoughts, beliefs, assumptions, and attitudes about the special characteristics of that specific domain. Therefore, the course contents and related practical experiences must be in-line with the professional requirements of the respective domain. Hence, selecting and implementing appropriate contents are very important for developing an appropriate mindset.

There is another important aspect which needs attention that is 'curriculum development processes'.Curriculum is more than a syllabus [26]. It not only provides a template or blueprint which enables learning to take place, but also reflects the societal, psychological and philosophical aspects of the society. One of the key functions of a curriculum is to provide the guidelines which enable learning that is expected to take place during a course of study in terms of knowledge, skills, competencies, attitudes and values [27,28]. An effective curriculum specifies the main teaching, learning and assessment methods and the learning resources require to support the effective delivery of the course contents[28, 29].

Many aspects of an effective curriculum have not been addressed in the revised curricula. For example, there are no guidelinesregardinglearning outcomes, evaluation strategies, instruction a methodologies, etc. This may be due to the absence of curriculum development experts from the curriculum revision teams. It is strongly recommended that the services of curriculum development experts may be co-opted during the curriculum development exercise. The participation of curriculum development experts would prevent many oversights which have identified in this study.Alternatively, training can be arranged for the curriculum development team.

The study believes these recommendations may help the concerned authorities to take appropriate measures to improve the quality and standard of computing curricula in Pakistan. The study outcomes may also help educators and administrators to make appropriate choices when developing teaching-learning strategies for computing programs at their institutions.

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