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A New Computer Engineering Curriculum Based on Technology Expansion to Address the Needs of Developing Communities*

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Computer engineering (CE) is a discipline that best serves the semiconductor, micro-architecture, computer equipment manufacturers, and other similar high tech industries which generally do not exist in developing communities. Therefore, there is often a mismatch problem between the curricula offered by CE departments and the actual needs of such communities. Nevertheless, most attempts for engineering curricula revitalization in developing countries focus on bridging the gap in applying the curriculum models, designed for, and meant to serve the developed communities. Hence, this work presents a new curriculum approach in which the student's learning experience is expanded outside CE to include a technology area of interest to the community. The article revises the typical CE curriculum model and visualizes it as a funnel structure, called the Single Funnel Model (SFM). SFM directs students to core computer engineering courses or courses in a specific concentration area. However, the need for concentration in developing communities with moderate-tech industries in a country like Saudi-Arabia is questionable. Hence, to better serve such communities, it is suggested that concentration areas be replaced by technology wide areas called Technology Expansion (TE) areas. Such a curriculum structure is called the Dual Successive Funnels Model (DSFM). To assess the problem and the suggested model, members of the academic community in the field in universities in the Middle East and Gulf countries were surveyed. The investigation revealed that the academics were, on the average, neutral on the extent of the problem, whereas they think that the new DSFM based on TE suits the needs of their developing communities better than the current SFM based on concentration. They also think that it can help the students develop their professional skills and lead to better integration in work environments.

Keywords: computer engineering education; curriculum modeling; technology based learning; SFM; DSFM

1. Introduction

Directing programs to the actual needs of a community can be challenging in developing countries. The engineering profession is challenged by the objectives of creating a sustainable world that provides a safe, secure, healthy, productive, and sustainable life for all people [1]. This necessitates educating engineers to become facilitators of sustainable development, appropriate technology, and social and economic changes [1]. After all, "Actual contribution to the development process of a country happens when the engineer, truly listens to the desires of those he/she is attempting to serve" [2]. In terms of curriculum development: "the engineering curricula in the developing countries should be revisited with a view to building into them, aspects that address national and regional needs" [3]. Hence, the thrill for adopting most sophisticated programs and state of the art technology and benchmarking with world top programs in universities in the USA or Europe is generally conflicting with the objective of serving real community needs.

Nevertheless, most of the attempts for engineering curricula revitalization in developing countries focus on bridging the gap in applying the recommended curriculum models designed for and meant to serve the developed communities. Examples are: to satisfy the curriculum requirements set by internationally recognized bodies such as ABET [4], to inflect a reform of teaching to overcome problems facing curriculum implementation such as students' background and lack of resources [3, 5], and to reconfigure the curriculum to match that of the westernized universities in countries facing complex political, economical, and social changes [6, 7]. What is not really addressed are curriculum changes that address the needs of the developing communities. Generally, much trust is given to western and international models. This is though that some western countries realized the importance of special education curricula to those coming from developing communities or intending to work there, e.g. the Engineering for Developing Communities programs (undergraduate and graduate) at the Mortenson Center in Engineering for Developing Communities at the University of Colorado at Boulder (https://mcedc.colorado.edu).

Computer Engineering (CE) was defined by the IEEE/ACM model curriculum report of 2004 [8] as a "discipline that embodies the science and technology of design, construction, implementation, and

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maintenance of software and hardware components of modern computing systems and computer-controlled equipment''. In its computing curricula overview report of 2005 [9], the IEEE/ AIS/ ACM rated, on a scale from 0 to 5, the performance capabilities of computing graduates in different computing tasks for five recognized computing majors of CE, computer science (CS), software engineering (SE), information systems (IS) and information technology (IT). Table 1 shows the rates of performance capabilities for CE graduate in some of the computing tasks. Tasks rated 5 are those related to low level hardware design and programming. Examples of these tasks are the tasks to *design/implement embedded systems*, to *design computer peripherals*, to *design complex sensor systems*, to *design/program a chip*, and to *design a computer*. It can be said that these are the main themes of CE. Tasks rated lower than 5 are most probably overlapping with other majors. For example the task to *do large scale programming* is rated 3 for CE, 5 for SE, 4 for CS and 3 for both IT and IS; this means that it is a task that computer engineers can do though it is done best by SE specialists. As another example, the task to *design/ program a chip* is rated 5 for CE, 1 for CS and SE and 0 for IT and IS which means that it is mainly a task for computer engineers. Also, the task to *develop corporate information plan* is rated 0 for CE and 5 for IS, which means that it is not a task for computer engineers but rather a task for IS specialists. Complete list of CE and the other computing majors tasks and their ratings for each major can be found in the ACM/ AIS/ IEEE-CS computing curricula overview report [9]. Based on these ratings, it can be said that the tasks of computer engineers are mainly hardware and programming at the device level with some branching into other tasks of other majors related to algorithms, application programs, systems development, resource planning, networking and information systems.

Table 1. Relative Performance Capabilities Of CE Graduates (Adopted From IEEE/ AIS/ ACM Computing Curricula Overview Report 2005 [9])

Task	Score
Design/ Implement embedded systems	5
Design computer peripherals	5
Design complex sensor systems	5
Design/ Program a chip	5
Design a computer	5
Do small-scale programming	5
Do systems programming	4
Create safety-critical systems	4
Install/upgrade computers	4
Develop solutions to programming problems	3
Do large-scale programming	3
Create a software user interface	3
Design network configuration	3
Design a database management system (e.g., Oracle)	2
Manage an organization's web presence	2
Select database products	1
Develop business solutions	1
Develop corporate information plan	0

The typical curriculum structure of CE which aims at empowering computer engineers with theses highly sophisticated tasks can be visualized as a funnel structure which starts wide by exposing the students to different foundation topics from math, engineering, electronics and CS and ends narrow with core CE courses or courses in a specific concentration area of CE. This is like a funnel's action, hence, the name ''Single Funnel Model'' (SFM) is used here to describe this kind of curriculum structure. The funnel in the SFM shall be referred to as ''the basic funnel'' in the subsequent discussion. In developing communities with moderate tech research and manufacturing work environments, it is unlikely that such device-level, highly specialized tasks and high concentration acquired in college be needed. This is in agreement with the study of Tedre et al. [10] in which it is suggested that the scope of IT education in Tumaini University at Iringa, Tanzania, must be broader than the scope of IT education in industrialized countries and the selection and emphasis of topics must meet the needs of Tanzanian society.

To elaborate, an example can do better; the Department of Computer Science and Engineering in the university of North Texas (UNT), Texas, USA, defines the mission for its CE major (http://www.cse.unt.edu/site/node/49) as ''to provide an educational program that is high quality, academically challenging and career-enriching. . .''. This is so far typical for any similar department anywhere. However, it continues: ''The degree further seeks to provide curricula that serve the citizens and industrial organizations in the United States and Texas in general and those in North Texas in particular.''. This last part encouraged to examine Texas state. First, it is found that Texas is home to Texas Instruments (TI), a world leader in semiconductor manufacturing, who made the first chip and the first electronic calculator. Additionally, many other world renowned semiconductor manufacturers such as Dell Computers, Samsung, Advanced Micro Devices, Raytheon, and STMicroelectronics are present also in Texas. In 2012, Texas ranked No. 1 in the US for electronic products and semiconductor components exports, No. 2 in electronics employment and No. 3 in output [11]. With such a huge base of the semiconductor industry, CE programs in Texas universities became a top priority and graduates enjoyed performing hardware design and microprogramming and other device-level tasks with a 5 rating for CE professionals.

This is in contrast to the case of a country like Saudi Arabia in which the semiconductor industry does not exist except in some government funded research centers and few electronic assembly manufacturing firms. As a result, most of the tasks that will be assigned to computer engineers in such a community will typically be more of support, IT resources management, installation, upgrading, networking and similar tasks rated 2 or 3 for them as CE professionals with rare or no opportunities that they perform tasks rated 4 or 5 for them. Such a situation puts pressure on computer engineers to work and excel in the fields of other computing professionals like IT support, IS specialists, and software engineers. This means that CE programs are, in fact, of minor importance to the community beyond portraying the image of providing high tech programs.

This does not mean giving up CE degrees, but rather to develop the curricula for CE in such a way so as to maximize the benefits of the programs to the surrounding modestly developed community. Universities in developing communities adopting CE curricula designed to serve the needs of high tech surroundings will not serve well the needs of their low tech surroundings. To better serve their communities, it is suggested here, as an approach to curricula rennovation, to replace concentration in a CE theme with expansion into a technology wide area that is wider than CE and of interest to the community. Examples of such technology areas are processing industry and mobile and wireless technology areas. This approach is called Technology Expansion (TE). Hence, the new curriculum structure will consist of the typical curriculum structure; i.e. the basic funnel of the SFM, followed by a second funnel, the TE funnel. This is called the Dual Successive Funnels Model (DSFM). The TE funnel aims to widen the student's horizon to encompass a technology area that may become his/her work area with concentration now focusing on core courses that best serve the area and is part of the general expansion goals.

The approach suggested here is an attempt to revitalize the curriculum that is typically proposed for developing communities. The author has suggested implementing this approach in the new computer college of Albaha university; in Saudi-Arabia. However, it will take several years before the impact of this new approach can be seen.

To initiate a discussion on the potential merits of this new approach, a description of the problem and the proposed changes to CE curricula was made available to a number of academics and decision makers in the field from different universities in the Gulf region and the Middle East. Those academics were also surveyed to determine if they actually think that a curriculum problem exists and if the proposed changes would benefit CE graduates and the industry. The end goal can be the inclusion of such agreed on approaches as alternatives to be recommended to developing communities as curriculum requirements to be imposed by local and international accreditation bodies.

2. Teaching—learning methodology/the curriculum models

Developing a new curriculum model requests first to inspect the teaching-learning methodology in CE using the typical curriculum structure. This is outlined in Section 2.1. Section 2.2 describes the proposed changes and the new curriculum model. The methodology used to assess the curriculum problem, the approach, and the new model and its potential benefits are outlined in Section 2.3.

2.1 The Typical curriculum structure—the single funnel model (SFM)

The typical model for computer engineering curriculum is visualized using a Single Funnel Model (SFM) shown in Fig. 1 with courses going down the funnel. The curriculum starts wide by exposing the students to math, physics, and electrical and electronic engineering concepts in order to enable them to grasp the core CE concepts that come towards the funnel's narrow end. In this way the funnel is a metaphor representing the curriculum parts that either provide foundations to other parts; e.g. the study of electronics is a prerequisite to the study of VLSI, or complement each other; e.g. the study of operating systems complements the study of computer architecture for a full computer system view. The teaching program's scope continues to narrow as we progress down the funnel till we reach its final learning objectives; i.e., the students become capable of performing the core tasks requested from the typical CE graduates.

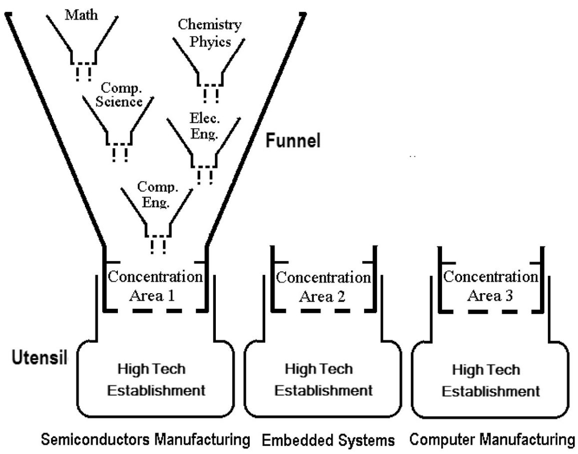


Fig. 1. The Single Funnel Model (SFM).

In other words, typical CE programs aim to enable the students in their final year of study to have a deep understanding in the field which entitles them to analyze and design processors, VLSI electronics chips, operating systems, embedded systems and other CE sophisticated tasks. In a developed community, like that of Texas/USA, these are typical work environment operations. Therefore, CE programs which aim to serve such communities will have to have curricula designed to achieve these goals. The SFM best describes the structure of the curriculum of such programs.

The study plan of a typical curriculum with the SFM structure classically starts with courses like calculus and physics followed by courses in statistics, linear algebra and discrete structures. Basics of electrical and electronic engineering can then be given in parallel with some signal and system analysis followed by combinational and sequential logic and state machine design courses. A course on digital electronics in which the design and analysis of practical logic families is needed at this stage to prepare for a higher course on VLSI technology and design. These can be as well paralleled with courses in algorithms, programming languages and other CS related courses. At this level, the students can also be taught microprocessors and assembly language programming and computer construction. After that, they can study operating systems and building device drivers. At this stage, the curriculum may include courses belonging to different areas of CE technology and applications, e.g. networking, real time embedded systems, operating systems, multimedia and digital signal processing. By now, the students had arrived at a fairly advanced level in CE. This can be approximately a full 4-year CE degree program.

In most of the 5-year and some 4-year CE programs adopting the typical SFM curriculum, the students in their final year of study are asked to choose an area of concentration from a list of choices (Fig. 1). Concentration areas in CE vary from one university to another. An example of such concentration areas is real time and embedded systems area which has applications in equipment and machinery like calculators, controllers, automotive, telecommunications equipment, and mobile phones. In such an area, the students are given courses on the hardware, software, and operating systems design of real time embedded systems. VLSI is another concentration area in which courses on VLSI design and testing, advanced digital systems, and embedded systems architecture are given. Other concentration areas are networking, computer systems, and communication systems.

In SFM, the whole curriculum (with the exception of the general electives that are not included in the discussion) is designed to arm the students with the background and all necessary tools to play their roles as computer engineers. Courses in the concentration area enable the students to start their job with ease in high tech establishments where the concentration area of any student might be his/her major work area. This does not prevent the graduate from being hired by another high tech company with a different major work area that is a bit far away from his/her concentration area. This is because all students should have been subjected to a common background necessary for most concentration areas. Also, concentration areas are themselves part of CE, and most well designed programs will introduce the concentration areas to all of the students through one or two introductory courses toward their fourth year of study. For example; in a concentration in networking, a course on basic networking is given; and for a VLSI concentration, an introductory course on VLSI and/or advanced digital electronics is given to all.

The SFM is most suitable for universities with high tech communities around capable of providing work opportunities focused on core themes in computer engineering, i.e. the utensil; the work concentration, is a narrow one matching the graduate's specialization. It helps the student in getting the right position and helps employers to select graduates that are appropriate for their needs. This model helps to advance the technology by satisfying the needs of high tech establishments of highly skilled and specialized computer engineers. Such a model can be a successful model for developed communities in high tech industrialized countries. Generally, the higher the technology the narrower the funnel's end, the apex, should be; i.e. higher concentration, to suit the technology narrow utensil (Fig. 1).

In developing countries, however, work opportunities do not focus on the core tasks of CE but rather on the wider, more general tasks rated 4 or less for the computer engineer. Engineers can even be asked to carry out non computing tasks or computing tasks that necessitate they know more about the general technology/ industry he/she serves. For example, a CE graduate who is being asked to install sensors and actuators and to program a PLC system to control an industrial process might need to determine himself the acceptable limits and tolerances on the process parameters. Therefore, it is necessary to make changes to the current CE curriculum model or have a new model that produce graduates who can handle tasks of such diversity and best serve their communities accordingly.

This argument is similar to the argument made in [12] to justify the need for socially aware software engineers for the developing world by saying that "Computer science innovation, when applied with a too narrow and technical focus, produces applications suitable for developed countries instead of solving local problems".

2.2 Curricula renovation—the dual successive funnels model (DSFM)

To justify more the need for a new curriculum model for developing communities; it may be useful to recall that concentration areas in CE degrees are focused around a partial list of the core tasks; e.g. a concentration area in VLSI will focus on chip design level more than system design level. In other words, concentration areas narrow more the students' scope. This calls for giving up concentration areas in CE majors. Additionally, CE is still a concentration area by itself in electrical engineering departments in many universities in the USA for example.

Here, it is not intended to give up the concentration areas for nothing. Instead, concentration areas shall be replaced by the wider scope expansion areas. An expansion area can be a technology representing a work sector in which CE graduates are hired because of the availability of sophisticated computing equipment and computerized controllers for machinery and processes. Computer engineers in such work environments are mostly concerned with tasks ranging from selecting the technology, its installation, management, updating, and maintenance with no or rare opportunities for low level programming and almost no opportunity for hardware chip or system design. The intention is to have a graduate with a horizon expanded to a technology area that he/she is likely to serve as a computer engineer, which fulfills the condition set up previously of the suitability of the funnel's apex (the graduate horizon) to the utensil's opening (the work area).

A curriculum model based on the idea of expansion is shown in Fig. 2. It is called the Dual Successive Funnels Model (DSFM). In DSFM, the output from the first funnel is a student educated as a computer engineer coming to his/her final year where typically concentration area courses are taught. However, instead of applying concentration, Technology Expansion (TE) funnel is applied (Fig. 2).

In TE, courses shall range from courses that introduce the technology basics to the students, this is the "Technology Introduction" constituent in the TE funnel in Fig. 2. A second component is a set of core CE courses that are mostly related to the technology itself; this is the "Computer Technology" constituent in the TE funnel in Fig. 2. Therefore, we can say that concentration is now part of the wider goal of expansion. A third constituent is the "Technology Blending Area" (TBA) which deals with ways CE is utilized in the technology. TBA courses may include the final year project in which the students utilize their CE know-how in solving the technology area problems. Core elective courses such as *advanced course on real-time embedded systems* can be reformed to become part of the TBA set of courses with the applications in them chosen from the technology area applications. TBA may also include an open course with a title like "Selected Topics in CE and the Technology of. . ." which tackles the technology changes and new innovations. Additionally, work ethics, communication skills, team-work, and other competency skills that are usually acquired from project course and dedicated courses may be now redesigned into the wider TBA.

In DSFM, input to the second funnel, TE funnel, is the output from the first one, the basic funnel. This is why it has been described as a "successive model". Notice that the apex of the second funnel is wider than the first funnel's apex targeting the wider work areas scope.

The DSFM for CE curricula provides a distinct model with a clear structure that can be differently used with different technologies of interest to different communities. Topics and details can be further tweaked to better address the needs of local communities.

The idea of expanding education is not a new one.

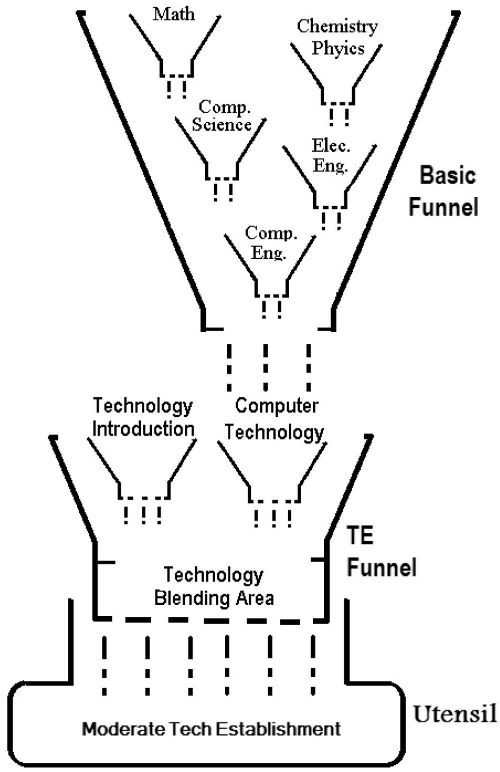


Fig. 2. The Dual Successive Funnels Model.

General electives and minor studies are typical ways of expanding the scope of education. However, such studies are different from the expansion idea in DSFM. The purpose of general elective courses is to introduce students to courses in other majors usually far away from their own emphasizing diverse life experiences. Minors can also be used to educate students in areas that can be far away or close to their majors and are selected to support certain students' intentions, however, the links between the student's minor and his/her major are typically created later in the real life environment. For example, a minor in management is appropriate for CE students intending to be in the technology business, and a minor in intellectual property rights or law can be useful for those looking for jobs in patents rights. Both general electives and minors produce an expansion in education targeting general or specific life goals. However, the purpose of TE using the DSFM is to help the CE graduate integrate easily in a job position in the technology area of his/her choice or in a similar technology or even in a different technology, which is possible, as he/she had been educated on the approach.

TE is best applied towards the final year of studies similar to the case of concentration with preferably one introductory course at some lower level of studies, especially when the degree program is offering more than one TE area for students to choose from. Therefore, TE is different from general electives and minors that are usually taught alongside the major. This is represented using the model shown in Fig. 3 which has two funnels as well, the large funnel stands for the major, and the other small one stands for the minor. However, the two funnels are independent. Therefore, the model in Fig. 3 can be called the Dual Parallel Funnels Model (DPFM) providing parallel funneling for specific life expansion goals. This is in contrast to the DSFM providing successive funneling for technology expansion goals.

The technologies proposed as TE areas should be intersecting with CE. It is not hard to find examples. In fact, most technologies will intersect somehow with CE. In the end, CE produce has become vital to all technologies in the form of computing equipment and interface products for machinery control, process monitoring, interconnecting, and computing cores. Technology examples of high relevance to Saudi Arabia's economy are: petrochemical process industries, food products and beverage industries, mobile and wireless technologies, water and sewage, railways, and electricity.

Courses suggested for any given TE area can vary depending on the area itself. For example, courses in the TE area of "Food Products and Beverage Manufacturing Technology" may include a general introductory course to the food and beverage processing technology and another course on the presence of computer technology in the food and beverage industry in addition to some pure CE related courses such as embedded systems, PLCs, and sensors and actuators, from which the student can select some. As another example, courses in the TE area of "Mobile and Wireless Technology" may include an introductory course on wireless and mobile networking and possibly an advanced course on the presence of computer technology in the mobile and wireless industry in addition to some pure CE related courses such as embedded systems, advanced wireless networking, security in networking, and high performance computing, from which the student can select some.

To explain how technology expansion may work, let us make an analogy with electronics technician profession. Electronics technicians have the core task of locating faulty electronic components and replacing them with new ones. They are taught on how to test the components. They may test them one by one in order to pinpoint faulty parts. While some do it this way, to save time and improve service, a system-wide troubleshooting is performed by higher level technicians who know about the interrelationships between the different components or the different stages in the device under repair. In troubleshooting, the technician checks the signal at some point, and if he finds that the signal level is ok, he can tell that all the stages that act to produce this signal are ok as well. Hence, in one test, tens or hundreds of components in these stages are declared non faulty thereby saving time and effort. Therefore, it is much more useful that electronics technicians be exposed to a certain technology area. Hence, some are taught to be, for example, radio

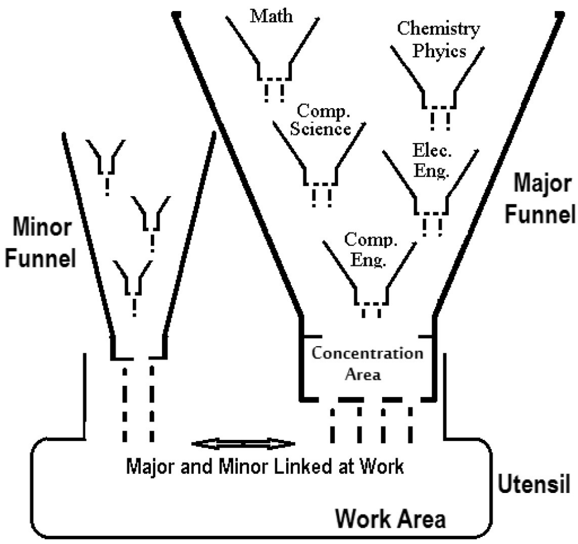


Fig. 3. The Dual Parallel Funnels model.

and television systems technicians while others might be taught to be biomedical equipment systems technicians.

Similarly, a computer engineer who knows about chips, operating systems, and computerized controllers is in a similar situation to the electronics technician who knows about testing components. However, both may benefit more from the full picture. Computerized systems in industries or certain technologies can have interactions using sensors and actuators with technology parts and stages all over the place. Even for a small sized system, like a mobile phone, the interactions within the phone itself might not be clear even though the core part of the phone is a processor and other VLSI components. In moderate tech industries the CE tasks are wider than a chip or circuit design, hence, it will be beneficial that the engineer sees more of the bigger picture.

Furthermore, TE can have the following impacts on the way computer engineers perform in positions in moderately tech jobs:

- Computer engineers will feel more comfortable about the general technology especially at startup. For example, computer engineers who had been in the mobile TE area at school will be aware of the wireless and mobile technology basic principles and the interactions with/within the computerized core of a base station and switching centers.
- Computer engineers will be aware of the roles and structural and special requirements of computing systems in such technologies. For example, the structure of computers used in office and home environments is different from the structure of computers used in industrial environments as they may be strengthened to protect against vibration, dust, and humidity. Also, as another example, there are super computers with large memory and tens or hundreds of processors working together to provide solutions to applications requiring a more reliable and faster computing power like weather forecasting, research, web servers applications, and telecommunications.
- Computer engineers will be aware of the role of the computing systems found in machinery and controllers, and how they interact with the larger systems. Therefore, they can perform the tasks of implementation, installation, and maintenance with higher confidence. They will be able to recommend technologies and better solutions.
- With time, they may perform some core tasks in CE. For example, they may reprogram/modify systems for better performance. This is because they were taught the technology and CE together. This is similar to the electronics technician who recommends a replacement for an obsolete part or sometimes design and implement an alternate circuit board.

2.3 Assessment of the problem, the approach and the new model

To assess the problem, the suggested approach to curricula renovation and the new curriculum model, by the academic community, a description of the problem and the proposed curriculum changes was prepared and made available to the surveyed individuals. A questionnaire designed to assess the respondents point of view on the problem and the methodology was designed. It consists of seven items divided in three groups, a group of three items with the objective to assess the extent of the problem, a second group of two items to assess the approach, and a third group of the remaining two items with the objective to assess the new model and its potential benefits. Each item is to be rated using a five-level Likert scale. The questionnaire has an extra field for more comments from the survey respondents. The survey was applied to a total of 41 individuals among academics and decision makers in the field from universities in Saudi Arabia, Jordan and other countries in the Gulf region and the Middle East. Respondents percentage responses on the Likert's five scale levels for each item will be presented together with each item's response average calculated based on a continuum scale of 5 (strongly-agree) to 1 (strongly-disagree). Also, a sum score is calculated for each of the three groups of items to be used to evaluate the average level of agreement (or disagreement) with each group objective.

2.3.1 Assessment of the problem

The first three items in the survey were used to assess the opinion of the academics on the extent of the problem of the mismatch between the curricula and the industry needs. The first item targets the academics' view on how much *CE graduates apply the complex knowledge they acquired in school in their daily work tasks*. The second item deals with their evaluation of *the suitability of CE curricula in developing countries for the actual needs of the community and industry*, and the third one is to assess *the need for concentration in certain areas of computer engineering for graduates working in developing countries.*

2.3.2 Assessment of the approach

The suggested approach to CE curricula renovation is based on two foci ideas; addressing the local industry and community needs in the curriculum design and expanding the curriculum to include wider technology areas of interest to the community. Hence, the next two items in the survey address these two issues, specifically, the first item is *the inclusion of aspects to address national and regional technological needs in CE curricula in developing communities* and the second item is *expanding CE students into certain technologies of interest to them or to the industry*.

2.3.3 Assessment of the new curriculum model

The last two items in the questionnaire were designed to obtain the academics' assessment of the new DSFM curriculum model and its potential benefits. One item is to *rate the new DSFM compared to the current SFM for suitability to the industry needs in the developing communities*. The other item is to evaluate how much *DSFM curriculum can help the graduates develop their professional skills and better integrate in work environments*.

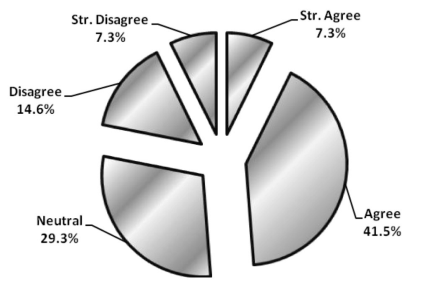
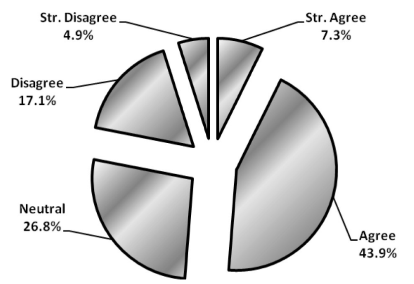
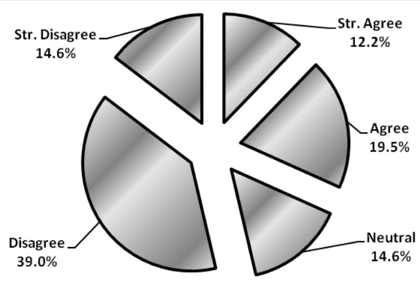
3. Results

3.1 Assessment of the problem results

The first three items in the questionnaire that are used to assess the academics' view of the extent of the problem are shown in Table 2, together with a chart showing the responders percentage responses on the Likert's five scale levels. From these results, item 1 response average is 3.3 (Neutral) which indicates that *the academics surveyed do not tend to agree or disagree (Neutral) with the belief that computer engineers in developing communities apply the complex knowledge they learned in school in their daily work tasks*. Also, item 2 response average is 3.3 which indicates that *the academics surveyed are also neutral with the belief that CE curricula in developing countries are suitable for the needs of their communities and industry*. They also were neutral (average 2.8) with the idea that *concentration is not needed for graduates working in developing countries*. The average score of the three items (after negating the results of the first two statements) was 2.7 (neutral) which indicates that the academics were not decisive on the existence (or the non-existence) of the problem.

Nevertheless, the problem can be justified by the fact that no agreement on ''no-problem'' existed augmented by the extra comments by some of them. Examples of their comments are:

Table 2. Assessment items related to the problem and the corresponding Pie Chart results

#	Item	Results
1.	*Computer engineering graduates in developing communities apply the complex knowledge they learned in school in their daily tasks at work.*	
2.	*Computer Engineering curricula in developing countries are suitable for the needs of their communities and industry.*	
3.	*Concentration in certain areas of computer engineering (e.g. VLSI, Computer architecture,... etc.) is not needed for graduates working in developing countries.*	

- You never know the future of the students,
- Some engineers might leave their developing communities to work in more mature environments,
- About 20% of our graduates currently work in the USA/Canada/Europe in industries that are nonexistent in the whole region (e.g. Microarchitecture and VLSI),
- To pursue the career of his/her choice, possibly outside of his/her country, and
- Remember that 20% of students go to complete their higher studies in renowned universities in the west.

Such comments may help explain the average neutrality result with the problem. The academics, apparently, care for preparing their students to apply state of the art technologies and practices and for matching their CE curricula to the needs of the developed communities. As a result, they were concerned that giving up concentration might conflict with these objectives.

3.2 Assessment of the approach results

Table 3 presents the items concerning the suggested approach and the corresponding results. On the average, the academics responded with a "Strongly Agree" (Average 4.5) on the item that *the curricula of CE in developing countries should be designed with built in aspects that address national and regional technological needs*. They also responded with "Agree" (Average 4.0) on the item that *it is beneficial if CE students are expanded in their studies into certain technologies of interest to them or to the industry*. Hence, we can say that the academics agree (sum score of 4.3) that addressing community needs through expansion into the technologies of interest to the community is an appropriate approach to curricula renovation.

3.3 Assessment of the new model results

Table 4 presents the academics' assessment of the DSFM. From the results in the table, the academics responded with an "Agree" (Average 3.6) on that *the suggested curriculum model; the DSFM, based on expansion, suits the needs of the industry in the developing communities better than the SFM based on concentration*. They also responded with "Agree" (Average 4.0) on that *DSFM can help the graduates develop their professional skills and better integrate in work environments*. Hence, we can say that the academics agreed (sum score of 3.8) on the new DSFM curriculum model and its benefits.

4. Discussion

From the results in the previous section, it is evident that the academics look for CE curriculum changes that consider aspects of the industry and community needs, and they find in the TE approach a possible candidate for renovation. They also think that the new DSFM with TE suits the needs of their communities better than the present SFM with concentration, and that the DSFM can help the graduates develop their professional skills and better integrate in work environments.

Table 3. Assessment items of the basic curriculum approach elements and the corresponding Pie Chart results.

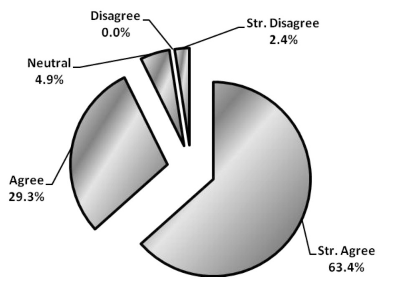
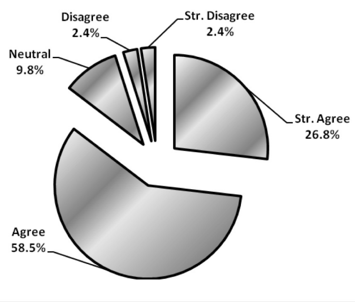
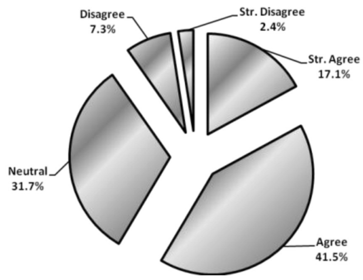
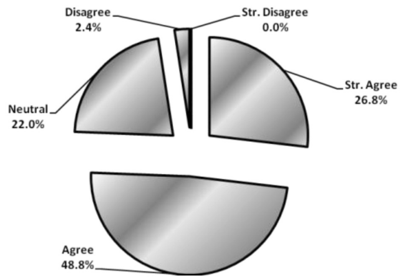
#	Item	Results
4.	*Computer Engineering curricula in universities in developing countries should be designed with built in aspects that address national and regional technological needs.*	
5.	*It is beneficial if computer engineering students are expanded in their studies into certain technologies of interest to them or to the industry.*	

Table 4. Assessment items of the DSFM curriculum and the corresponding Pie Chart results

#	Item	Results
6.	*The suggested curriculum model (DSFM), in which the student is expanded into a technology area of interest, suits the needs of the industry in the developing communities better than the concentration (SFM) approach.*	
7.	*The suggested curriculum approach (DSFM) can help the graduate develop his/her professional skills and better integrate in work environments.*	

4.1 Benefits of the approach followed for promoting professional skills

In the previous section (Table 4), it is shown that about 76% of the academics surveyed are with (agreed or strongly-agreed) the statement that the new DSFM can help the graduates develop their professional skills and better integrate in the work environments. Nevertheless, this approach to curriculum structure can be argued to have both pros and cons as follows:

- The expansion prepares the students to specific technology/work areas. This means that the students will not need to be retrained by the employers. Generally, "any computer and information technology (CIT) course that ignores the needs of industry completely would not survive for long, thus trends in industry influence CIT curricula" [13].
- However, it can be said that this is a bachelor's academic degree program and not a vocational or a technology program or as said in [14] that "future computer engineers must be equipped with essential knowledge and well-tested methods and techniques, not just transient technologies".

  To reply, it is worth to remember that in this approach no suggestion is made to give up essential knowledge, methods and techniques, after all, the new DSFM structure retains the basic funnel (the SFM) representing the typical CE structure. This approach is somehow similar to the final year project in which the students exercise applying essential knowledge and methods in solving problems of other disciplines which necessitate that they learn a little bit on the other disciplines while enhancing CE learning in what is usually called project based learning (PBL). Similarly, TE is a bigger exercise in applying computer knowledge and methods to the wider technology area. It encompasses more CE learning while at the same time provides enough technology specific learning as if it is a related minor study that can enhance the graduates' work opportunities. We may therefore classify the learning obtained this way as Technology Based Learning (TBL).
- Though TE prepares the graduates for a specific technology, it is not necessary that they work in their individual TE areas, though it can be advantageous. The graduate shall have the capability to be in other areas as well. This is because, in TE funnel, few courses shall be directed to the expansion technology itself while the remaining courses are pure CE modules that best serve this technology, e.g. the networking and security course is suggested for Mobile Networking TE track, and the embedded systems course is suggested for the process industries track. Both those two courses are pure CE courses. Additionally, the graduate may project the methodology learned from studying specific TE area onto another technology area.
- Universities may solicit technology sector support for internships, securing student jobs, and making use of the industry related experts to teach technology related courses. Also, the academics can provide consulting and research work

to solve industry problems. Final year projects can be oriented to solve real problems in the sector.

- It is not clear how accreditation bodies like ABET, the Accreditation Board of Engineering and Technology, will look at the issue. Generally, some of the concentration areas already adopted in some accredited universities are more like an expansion rather than a concentration (Example, the concentration in Communications and Networking). Boston University in the USA, offers two expansion technologies (though they still call them concentration areas probably for accreditation requirements). These are: *Energy Technologies and Environmental Engineering* and *Nanotechnology*. The area of energy and environment is much wider than CE and is given to students interested in the impact of energy innovations or green technology. Nanotechnology is about developing materials of the size of atoms or particles, which includes chemistry, biology, and other sciences. CE intersects with this technology since developing micro devices and sensors is part of nanotechnology. The website (www.bu.edu/ece/undergraduate/computer-engineering/) advocates these specialized concentration areas as they act to "add another dimension to the bachelor's degree at a time when the demand for interdisciplinary engineers is growing". This can be added to the advantages discussed so far; i.e. this model can probably be advantageous to computer engineers in developed countries as well.

4.2 *Future issues*

One of the surveyed academics added the note: "In the race to obtain accreditation of engineering degrees from US and UK educational organizations, almost all universities of the Middle Eastern region ignore the fact that the educational needs of their engineers are different from those of the US/UK engineers; so teaching a curriculum which suits a student in an advanced country does not necessarily fit perfectly for a developing region such as the Middle East". This work is one attempt to pinpoint the problem and to suggest a solution. Generally, the suggested approach requires more research.

Based on the survey results, the following two issues deserve more consideration.

1. Academics surveyed were neutral with the statements that "CE graduates in developing communities apply the complex knowledge they learned in school in their daily tasks at work.", and "CE curricula in developing countries are suitable for the needs of their communities and industry.". With the help of the respondents' comments it was deduced that academics care for the future of their students who may end up working/studying in developed countries. This proposition deserves further consideration in research. After all, developing curricula that is appropriate to both worlds can be a challenging one.
2. Academics surveyed generally agreed with the statement that "DSFM suggested suits the industry needs in the developing communities better than the concentration (SFM) approach" while at the same time were neutral with the statement "Concentration in certain areas of CE is not needed for graduates working in developing countries". As previously mentioned, concentration in the suggested approach lies within the general scope of technology expansion and is not totally given up. This is a point that deserves more consideration to arrive at the proper compromise between concentration and technology wide expansion.

5. Conclusions

This paper is about a new computer engineering (CE) curriculum to address the needs of developing communities. For that, a model for the traditional curriculum architecture of CE called the Single Funnel Model (SFM) is envisioned (Fig. 1). This model can best describe the current curriculum structures in most universities everywhere. It fits a CE degree in CE departments with concentration areas centered around one concept in CE hardware or hardware related software such as VLSI, real time and embedded systems, and computer systems.

An argument was built around the need for such concentration areas for the developing communities. Hence, to better serve the needs of the community, it was suggested that concentration areas be replaced by Technology Expansion (TE) areas. The curriculum designed this way was modeled as a Dual Successive Funnels Model (DSFM) (Fig. 2). In DSFM, the output of the first funnel, the basic funnel, is a student who has almost completed the necessary CE core courses together with their foundation courses. The TE funnel follows the basic funnel and expands the student's horizon into a technology area of his/her choice through a concentrated set of CE courses that best serve the technology plus courses on the technology itself and project work or other special courses that help merge the two themes.

Assessment of the problem of mismatch between the curriculum and the actual needs and the suggested DSFM approach was conducted by surveying academics in the field. On the average, the surveyed academics did not agree or disagree (Neutral) with the belief that computer engineers in developing communities apply the complex knowledge they learned in school in their daily work tasks. They were, as well, neutral with regard to the belief that CE curricula in developing countries are suitable for the needs of their communities and industry, and they were also neutral with the idea that concentration is not needed. The extra comments made by the academics were used to interpret the average neutrality on these issues. It is believed that the academics were worried for the future of their students who may work/study in the developed world.

On the other hand, the academics surveyed confirmed decisively the following:

- They "strongly agreed" that CE curricula should be designed to take into consideration local and regional needs.
- They "agreed" that the idea of technology expansion can be beneficial to the graduates.
- They "agreed" that the suggested DSFM suits the industry needs in their developing communities better than the concentration (SFM) approach, and
- They "agreed" that DSFM can help the graduates develop their professional skills and better integrate in work areas.

This approach is open to research from many angles. It will be impressive if this work prompts some community thinking about it and other similar approaches that can really revitalize CE curricula in the interest of developing communities.

References

1. B. Amadei and R. Sandekian, Model of integrating humanitarian development into engineering education, *Journal of Professional Issues in Engineering Education and Practice*, **136**(2), 2010, pp. 84–92.
2. L. Parsons, Engineering in Context: Engineering in Developing Countries, *Journal of Professional Issues in Engineering Education and Practice*, **122**(4), 1996, pp. 170–176.
3. K. I. Dabipi, J. N. Dodoo, J. B. Burrows-McElwain and C. Hartman, Adapting Engineering Education Curriculum for Global Competiveness in Developing Countries, *Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments, 2010 IEEE*, Dublin, Ireland, Apr. 6–9 2010, pp. 1–8.
4. E. Erdil and A. Bilsel, Curriculum design to revitalise electrical engineering education at Eastern Mediterranean University, *International journal of electrical engineering education*, **42**(3), 2005, pp. 234–246.
5. P. Song, X. Song and T. Yang, Exploration on the reform to teaching of basis of computer engineering in universities, *Int. Conf. on Computer Science and Service System (CSSS), 2011*, 27–29 June 2011, pp. 401–403.
6. P. Navrat and L. Molnar, Curricula transformation in the countries in transition: an experience from Slovakia, *IEEE Transactions on Education*, **41**(2), 1998, pp. 88–91.
7. H. Jaakkola and A. Kalja, Improving IT education in Estonian universities, *Innovation in Technology Management—The Key to Global Leadership. PICMET '97: Portland International Conference on Management and Technology*, 27–31 Jul 1997, 1997, pp. 276–279
8. IEEE-CS/ACM, Computing Curriculum-Computer Engineering Final Report, 2004. http://www.eng.auburn.edu/ece/CCCE/CCCE-FinalReport-2004Dec12.pdf, Accessed 18 May 2013.
9. ACM/ AIS/ IEEE-CS, Computing Curricula 2005- The Overview report, 2005. http://www.computer.org/portal/c/document_library/get_file?p_l_id=2814020&folderId=3111026&name=DLFE-57601.pdf, Accessed 18 May 2013.
10. M. Tedre, N. Bangu, and S. I. Nyagava, Contextualized IT education in Tanzania: Beyond standard IT curricula, *Journal of Information Technology Education*, 8(1), 2009, pp. 101-124.
11. The State of Texas, Office of the Governor, The Texas electronics Industry, 2013, http://governor.state.tx.us/files/ecodev/Texas_Electronics_Report.pdf, Accessed 07 Oct. 2014.
12. E. Blake and W. Tucker, Socially aware software engineering for the developing world, *Proceedings of IST-Africa 2006, Pretoria, South Africa, 3–5 May 2006.*
13. B. Pham, The changing curriculum of computing and information technology in Australia, *Proceedings of the 2nd Australasian conference on Computer science education*, ACM, 1997, pp. 149–154.
14. A. McGettrick, M. D. Theys, D. L. Soldan and P. K. Srimani, Computer engineering curriculum in the new millennium, *IEEE Transactions on Education*, **46**(4), Nov. 2003, pp. 456– 462.

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