# Reshaping Curriculum Design from Concept to Assessment through Technology Driven Methodologies

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## Abstract

The purpose of this work is to amalgamate technology and education in a manner that is beneficial to stakeholders in the educational sector. The motivation surrounds the issue of limited human resources i.e. teachers, expert knowledge, and available classroom resources. In many developing countries, the student-teacher ratio is high and this framework addresses this issue. This work has the potential to be also of benefit to developed countries.

This work highlights the need for qualitative, seamless, and systematic design of curricula, and demonstrates that utilizing technology enables educators to increase productivity and efficiency. Modeling a curriculum that allows for the concrete mapping of objectives to content, and content to assessment provides vast benefits. These benefits include automatic generation of assessments, automated assessment of students, and more focused analysis of student performance and learning outcomes. Educators can make decisions about improvements, or changes that need to be made in a curriculum.

# 1 Introduction

Despite the advances in technology, there still seems to be limited utilization of such technology in the field of education. While there is a belief that technology could improve the educational productivity and help schools to teach more efficiently, evidence to support this belief is scarce [1]. Indeed, while the business landscape has seen a dramatic transformation due to the integration of technology, this sort of impact in educational institutions has been modest. There remains a very broad spectrum in which the harnessing, utilization and integration of technology would prove beneficial to the development, delivery and assessment of education. This work is not merely trying to address an existing problem, but rather will strive to chart a path towards a new paradigm in teaching and assessment from the ground up.

## 1.1Amalgamating Technology with curriculum design

The fusing of technology with curriculum design will result in benefits being derived long after the actual curriculum has been created. Incorporating technology into the design process will allow educators and other stakeholders to capitalize on a framework which relies on the systematic and methodical modeling and presentation of related artifacts. The basic idea is to integrate technology from the ground up, that is, from the beginning point of the entire process all the way through to assessing what was taught.

Traditionally, technology in education has been viewed in two ways; as a transmission device and as a learning device [1]. According to [1], too much emphasis has been placed on learning from technology (e.g. viewing educational television, computer drills etc.), rather than learning with technology. It has also been argued that traditional teaching involved the dissemination of information from the front of the room, assigning chapters from text books, and grading worksheets and exams rather than helping each student search for personal understanding [2]. Figure 1 illustrates this traditional view schematically. The aim of this research is not to adopt these existing views, but rather to go a step further in an attempt to integrate technology in one of the foundational pillars of the educational process; that of the development of curricula. Remember, that without any set goals (a 'roadmap' of sorts), how can one know what it is that ought to be achieved and hence how and what it is that ought to be taught. Therefore, the view of technology in education will be changed from the standpoint of this research to reflect a model that more closely resembles the one shown in figure 2 below. The idea here is to not just continue integrating or improving the use of technology in curriculum, but to also utilize technology in the development and refinement of said curriculum. Refinement is mentioned here to emphasize the use of technology in the continued improvement and positive modification of a curriculum through feedback, assessment analysis and student learning outcomes (psychomotor, cognitive, etc.).

One of the focal points of this research is to look at the integration of technology into curriculum development holistically. That is, there is a need to go beyond the traditional view of simply using technology in the classroom to aid in the delivery or teaching of a subject for instance. To this end, there needs to be an effort to get to a point where technology is much more involved in the overall process from the actual selection of content for a curriculum to even the assessment of student performance (learning outcome) and the feedback of such assessment to inspire positive changes in a given curriculum.

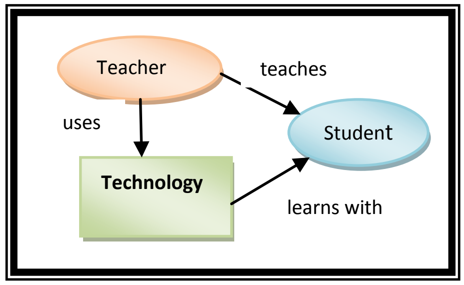


Figure 1: Traditional view of technology in education

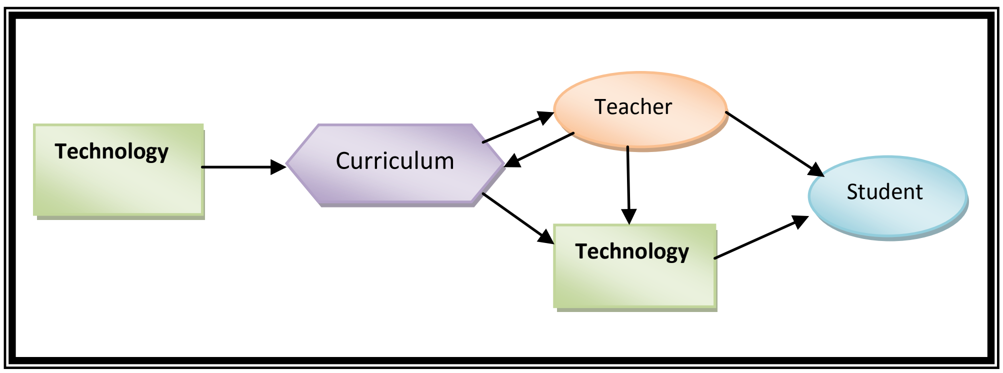


Figure 2: Future of view of technology integration in education

## 1.2 The need for systematic curriculum design

A curriculum can be described as the embodiment of a program of learning which is the aggregate of courses of study given in a school and includes philosophy, content, approach and assessment. Given this view, a curriculum is a very important aspect of any educational program. Therefore, if this process can be formalized in a more rigid way, the benefits to be derived will be quite immense. Also, because of the fact that this process is one that virtually every established educational institution and program must partake in, then it stands to reason that greater care and emphasis must be taken. Hence there is an inherent need for the systematic designing of curricula.

This research effort will essentially leverage the use of technology in a new paradigm for teaching and assessment. The framework that will be created will present a collection of artifacts that will help educators to more easily manage a curriculum and to more easily manage assessment of students. This model is a push toward greater coupling of content and assessment and is an innovative way of modeling and representing such educational artifacts.

## 1.3 What is a Curriculum and what constitutes it?

The term curriculum is often times misunderstood, misrepresented and takes on different meanings in different contexts. It is therefore very difficult to find a common definition for the term. In simple terms, however, a curriculum is the embodiment of a program of learning which is the aggregate of courses of study given in a school and includes philosophy, content, approach and assessment. But what is this embodiment? In some sense, a curriculum can be referred to as any document that exists in a school that defines the work of teachers by identifying the content to be taught and the methods to be used [3]. In most of today's educational settings, such a document even in a digital form is quite static, and not flexible to the needs of the beneficiaries.

From the simple definition above, philosophy would include the implicit and explicit standards and expectations that ought to be captured and in the entire teaching and learning process in a given institution or department or setting.

At this juncture, it would be useful to mention a few of the alternative views on a curriculum in schools. Educational theorist Larry Cuban [4] suggests that there are at least four different curricula utilized in schools:

- The official curriculum – what the policy makers or other authoritative body sets forth and is precisely what teachers are expected to teach.
- The taught curriculum – what teachers actually end up teaching or what they choose to teach in their individual settings and circumstances
- The learned curriculum – unspecified lessons that students learn which are embedded in the classroom environment
- The tested curriculum - a subset of the official, taught and learned curricula for which students are evaluated on.

In the brief description outlining the four different curricula above, it is clear to see the conundrum which results with the implementation of a curriculum (what is actually taught) and in assessing students (tested what has been taught and learned). Assessment is really two-fold because it helps to determine what was taught and what was learned. But in fairness to the educators, the results of a test does not conclusively suggest that a given topic was not taught or taught properly because a student may not have learnt that which was taught, which may not be the fault of the teacher. This is one of the issues that the proposed paradigm will address because a system designed using this framework will readily create an assessment given a set of teacher-defined parameters and determine how much of a course's content is covered in a given test. Larry Cuban in [4] also suggests that what is tested is a limited part of what is intended by policy makers, taught by teachers and learned by students and further that standardized tests often represent the poorest assessment of the other curriculums. A major problem with standardized tests is that teachers are far removed from the actual construction of the test which results in a greater disparity between what is being tested and what was taught and learned. The proposed paradigm would fit nicely in a solution for this problem because a framework would be in place for teachers to be able to dynamically design an assessment tailored to their specific needs and environments. In different institutions and across national borders, "one size does not fit all." Hence there is the need to put the control of assessments in the hands of those who are delivering the curriculum and that curricula must be designed with the users and the environment for which it will be utilized in mind. The main idea here is that this task can be done easily, automatically correctly.

Another perspective of curriculum is that of the Null curriculum. This notion is put forward by Elliot Eisner in [5] which suggests that what curriculum designers and/or teachers choose to leave out of the curriculum is no less important than what they choose to include and that those choices are based on a number of factors. Some of these factors include personal beliefs, knowledge and skill level of the educators, and cultural nuances of the curriculum designers. This is an important point because the proposed paradigm will expressly model such factors both in terms of the rationale for choosing certain topics while omitting others.

### 1.3.1 The Parts of a Curriculum

A curriculum is not simply a document that contains a list of objectives and the topics that would fulfill each objective. But it is much more involved that this, in that it embodies the educational process in a holistic way. The Duke Centre for Instructional Technology [7] postulates that there are six distinct part to any curriculum. These parts are concisely presented as follows:

1. Needs Assessment – evaluates the need for such a curriculum,
2. Rationale – justifies the proposal and is based on the needs assessment
3. Goals and Objectives – the core of the curriculum which presents specific skills, knowledge and attitudes that learners ought to achieve through the program,
4. Teaching and Learning Strategies – these are essentially the “how” of the curriculum and include methods that will be utilized in the delivery of the material such as lectures and projects,
5. Evaluation Strategies – methods of measuring the objectives achieved from the perspectives of the learners, the educational methods and the overall program,
6. Management Plan – this is the implementation which takes the curriculum from design to use.

All the parts of a curriculum are clearly important and must be addressed at some point throughout the design process by various stakeholders. For instance, the needs assessment may be important to faculty members who actually teach a given course. So that need may be initially raised by some faculty member who will then need to justify such a need to perhaps the school board or the universities president. Therefore, certain aspects of the design process are inherently administrative, and so for the purposes of this work, such aspects will be abstracted away. This will be done in an attempt to keep the focus on the scope of this work which assumes that parts one and two listed above have already been done. The focus is therefore on parts four through to six and each of those four individual parts will be addressed and incorporated in the proposed paradigm in some way.

# 2 Motivation

The scarcity in human resources in the way of lecturers, faculty and generally experts in the related field has been a barrier to the effective delivery of standardized world class curriculum in developing countries. Many higher education institutions there do not have faculty with PhDs (not to say that a lecturer with a PhD is the ‘be all and end all’, but a certain level of credibility and authority comes with it).

This framework will ease the burden that such underserved institutions and territories bear by making available a common pool of resources necessary for teaching and assessment.
Sub-standard and limited physical resources such as communications equipment (broadband internet, wired or wireless phone infrastructure) in varying degrees has also contributed to the educational gap and lack of coherency which exists between developed and developing countries. Furthermore, within the borders of a developing country, one may find that the expertise and available resources are only available in the urban centers, thus limiting accessibility and compounding macro-economic issues such as ‘brain drain’. This gap can be expounded by examining the scenario in which a student with an undergraduate degree from Jamaica (a developing country) is not viewed in the same way as a student from the United States who has a similar undergraduate degree in the same discipline. It is for this reason that many colleges require a Graduate Comprehensive examination for students wishing to matriculate in a graduate program. This exam attempts to ensure that all students in their graduate program have successfully mastered the undergraduate level programs regardless of where such programs where taken. Most US universities also require a Graduate Record Examination (GRE) whether it is a general or subject test for much the same reasons. This incongruent view is not necessarily a matter of culture, but one for which there is some merit because of the fact that as things stand currently, two courses having the same name and taught in two different countries does not mean that the content or delivery is the same.

## 2.1 High teacher to student ratio

It has been found that there is a high teacher to student ratio in developed countries virtually at all the levels in the education system. This again, is another marked difference between what obtains in the classroom in a developed country versus a developing country. In conditions where one teacher is responsible for too many students, the individual attention that each student needs may be lacking in terms of post assessment, feedback and overall progression evaluation. A framework such as that proposed in this research will significantly reduce the negative impacts that such high ratios have on both the teaching and learning process.

## 2.2 International collaboration and a common pool of resources (repository)

This new paradigm will work well in an international setting wherein the internet will act as an enabler in this regard. Once the repository is set up, the common pool of resources will be available internationally, thus strengthening the collaborative efforts between higher learning institutions. This will also bring into closer alignment the notion of a standardization of curriculum and minimum quality thresholds.

## 2.3 The need for a minimum quality threshold

A program of study taught in different regions of the world often has differing outcomes and qualities. Especially in disciplines which are young (like Software Engineering) and still developing, the disparity may be quite significant. Therefore it is very important to have a minimum standard which defines the quality of a curriculum. In this way, there can be the establishment of certain standards which direct and guide the overall effort. Thus maximizing on the expert knowledge in the particular field in which the system is utilized. For instance, a student pursuing a Bachelor of Science in Computer Science with a Software Engineering major in Jamaica (a developing country) and being taught by faculty with M.Sc. degrees should have a similar learning outcome as a student in the USA (a developed country) doing a similar program of study and taught by faculty with PhDs. Therefore, regardless of where the curriculum is utilized, there should be a minimum standard that is achieved, below which the quality cannot be guaranteed. Having used the previous example is not an indictment on the teachers/faculty, because the degree that a teacher has does not determine the outcome of their students. Thus the example is used here to make the distinction that the quality of a curriculum varies tremendously from institution to institution and this is the greater problem that needs to be addressed.

## 2.4 The need to establish measurable goals (learning objectives) tightly coupled with student learning outcomes

A famous quote by Fitzhugh Dodson reads "Without goals, and plans to reach them, you are like a ship that has set sail with no destination." In a similar light, it is very important to have well-established goals in any program of study. Hence, there is a need to have measurable learning goals (objectives), and further to tightly couple such objectives with learning outcomes. Doing so will facilitate the seamless assessment of students in that it will be easier to compare student learning outcome to learning objectives. There are curriculum information management systems which do exist, but these take a perspective which is more targeted towards administration such as accreditation issues, skill-set mapping and quality control. The new paradigm being suggested in this work will go much deeper in taking the perspective of teaching and learning in the classroom and packaging all the relevant aspects in a systematic way.

## 2.5 Meaningful and automatic assessment of students

One of the distinct benefits of this new paradigm is that it will allow for meaningful and automatic assessment of students. This will be especially useful in developing countries where the high student to teacher ratio means that educators do not have the time to give individual attention to all students. Automatic assessment means that the system can take a student's raw score and based on certain characteristics of the assessed content along with certain parameters/metrics, an automated evaluation of that student can be made. This evaluation may include recommendations and other qualitative analyses.

## 2.6 Automatic generation of assessments

Educators need only specify the parameters they want the students to be assessed on and the system will automatically generate the questions. The success of such a scenario will depend on a question bank that is supported by contributors and authorities in the given domain such that every question is tagged in a manner which will link it to a specific content or set of contents (see figure 3). The idea here is that based on the fact that there will be a rigid content to assessment mapping, every question can be tied to some content and in so doing one the system can easily generate for instance a test containing a set of questions given the criteria of a content of set of contents.

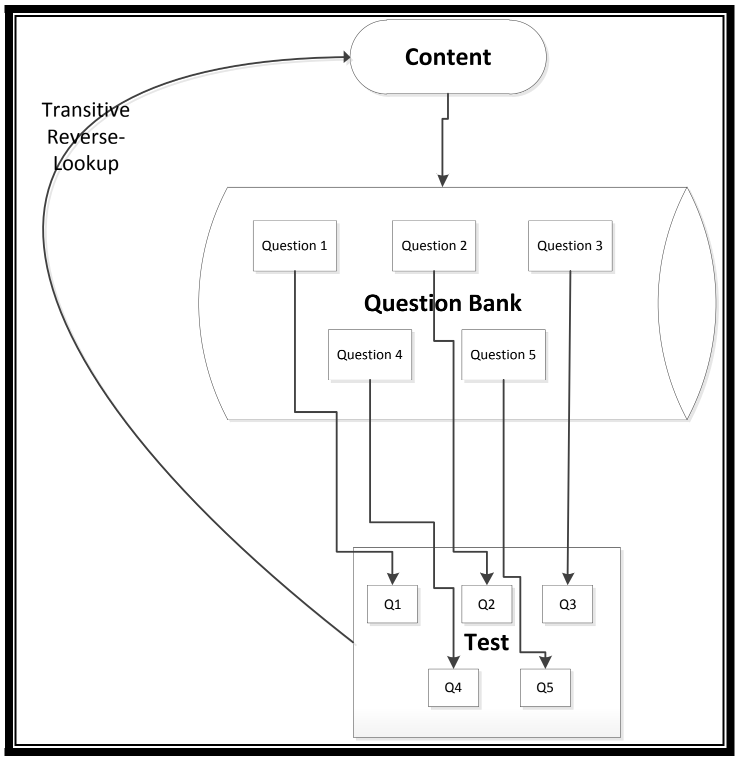


Figure 3: Mapping Content to assessment

# 3 Research Methodology

This framework is potentially useful across many domains and utilizing it as a template in any one domain theoretically means it will be useful in others. However, for the purposes of this paper, the Software Engineering discipline will be used as a model to demonstrate this framework. In other words, a Software Engineering Model will be used as a case study in this research. Software Engineering is a STEM (Science, Engineering, Technology, and Mathematics) discipline and as mentioned before, it is hoped that such a paradigm as that proposed will be applicable to any STEM discipline.

## 3.1 The importance of rigid objectives, content and assessment mapping

The objectives of any curriculum are a critical component and can be viewed as a starting point or a beacon which acts as a guiding light for the entire effort. In the same light, the objectives themselves cannot stand alone. The objectives guide the selection of content, and it is the delivery of said content which helps to fulfill the objectives. Therefore, if one were to abstractly look at this process from a top-down approach, it can be seen that it is fairly easy to rigidly map objectives to content. A given objective may map to one or more content or content areas, while a given content may be mapped to one or objectives.

A foundational principle of this system is the notion of hierarchy or better yet, granularity. The levels of abstraction are very important and so the artifacts of the system can be viewed from top-down o bottom-up. The two examples in figures 4 and 5 below sum up this notion:

| **Stakeholders who will benefit** |
|---|
| Students |
| Teachers |
| Administration |
| Institutions |
| Educational Sector |
| Governments / Countries |
| The World |

Level of Abstraction

Figure 4: Increasing levels of abstraction

| **Curriculum** |
|---|
| Domain e.g. Aerospace, Compu Science |
| Program Curriculum |
| Subject Area |
| Course |
| Section |
| Topic / Sub-Topic |
| Atomic Unit |

Level of Abstraction

Figure 5: Decreasing levels of abstraction

Another major feature of this framework is the notion of scalability. This is an important feature because the system must provide a mechanism for the systematic design of curriculum which reduces the complexity of an otherwise complex task. Scalability in this context will allow for consistent usability throughout, from early in the design process to the end as well as from a size aspect, that is, whether the curriculum is small or large.

In the previous paragraphs the importance in mapping objectives to content was mentioned. Here, a similar approach obtains, however, the focus here is the mapping of content to delivery and assessment. Tightly coupling content to assessment especially will provide many benefits such as that of automated assessment generation. But more importantly, the hierarchical approach mentioned earlier will be maintained which will lead to many other possible benefits and use in this framework.

## 3.2 A Framework Input Source: IEEE-CS/ACM SE Curriculum Guidelines

It is anticipated that the major source of input for the content and the initial framework is the Institute of Electrical and Electronic Engineering Computer Society (IEEE-CS) and Association of Computing Machinery (ACM) Software Engineering 2004 Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering (IEEE-CS/ACM SE 2004). The purpose of this document is to provide guidance about what should constitute and undergraduate Software Engineering education. The recommendation found therein have been developed by a broad, internationally based group of volunteer participants which took into account much of the work that has been done in software engineering education over the last quarter of a century. Such a document as this is of great importance given the current surge in the creation of software engineering degree programs.

The IEEE-CS/ACM SE document is just a guideline for what should constitute a curriculum, and so the framework will allow for the input of experts in the field from around to world to contribute to it and make it better. The idea is not to re-invent the wheel by trying to redo the work that has gone into the IEEE/ACM SE document, but rather to take that document and use it as a source of input for this framework.

### 3.2.1 Summary of IEEE-CS/ACM SE document

The body of knowledge that is deemed as appropriate for an undergraduate program in software engineering is designated as SEEK (Software Engineering Education Knowledge). According to [8], knowledge is a term used to describe the whole spectrum of content of the discipline to include information, terminology, artifacts, data, roles, methods, models, procedures, and so on. SEEK is organized hierarchically into three levels.

The highest level is the education *knowledge area* which represents a particular sub-discipline of software engineering that is generally recognized as a significant part of SE knowledge that and undergraduate should know. The second level is called *units* where each knowledge area is broken down into smaller divisions. Each unit is then subdivided to form the lowest level which is a set of *topics*.

# 4 Remodeling/Reshaping the Curriculum Design Process

This work serves as a proposal for a paradigm that will significantly improve the way in which curricula are designed and delivered. Also, there will be many benefits to be garnered from taking the proposed approach. This paradigm will be applicable to any STEM discipline and the scope of this work will be limited to a case study of its use with Software Engineering. An abstract view of the framework is depicted in figure 6 in which a hierarchical outline is given. In this work, the Software Engineering curriculum in the field of Computer Science will be used as the working prototype. Thus for a given four year undergraduate degree program, a system derived from this framework will be able to for each year:

- Present all the teaching and learning goals
- Provide access to all relevant content in terms of a set of topics
- For each topic, show the recommended delivery (teaching) methods and required resources. For topics which are not selected, alternatives may be suggested, but regardless of whichever topics constitutes the content, the coverage metric (a measure of how much of the curriculum is covered or selected) will be given.

- Recommend relevant assessment methods and provide automated assessments which are mapped directly or indirectly to the content.
- Provide analysis of student learning outcome which allows for a comparison between performance and expectations (feedback between outcome and objectives).

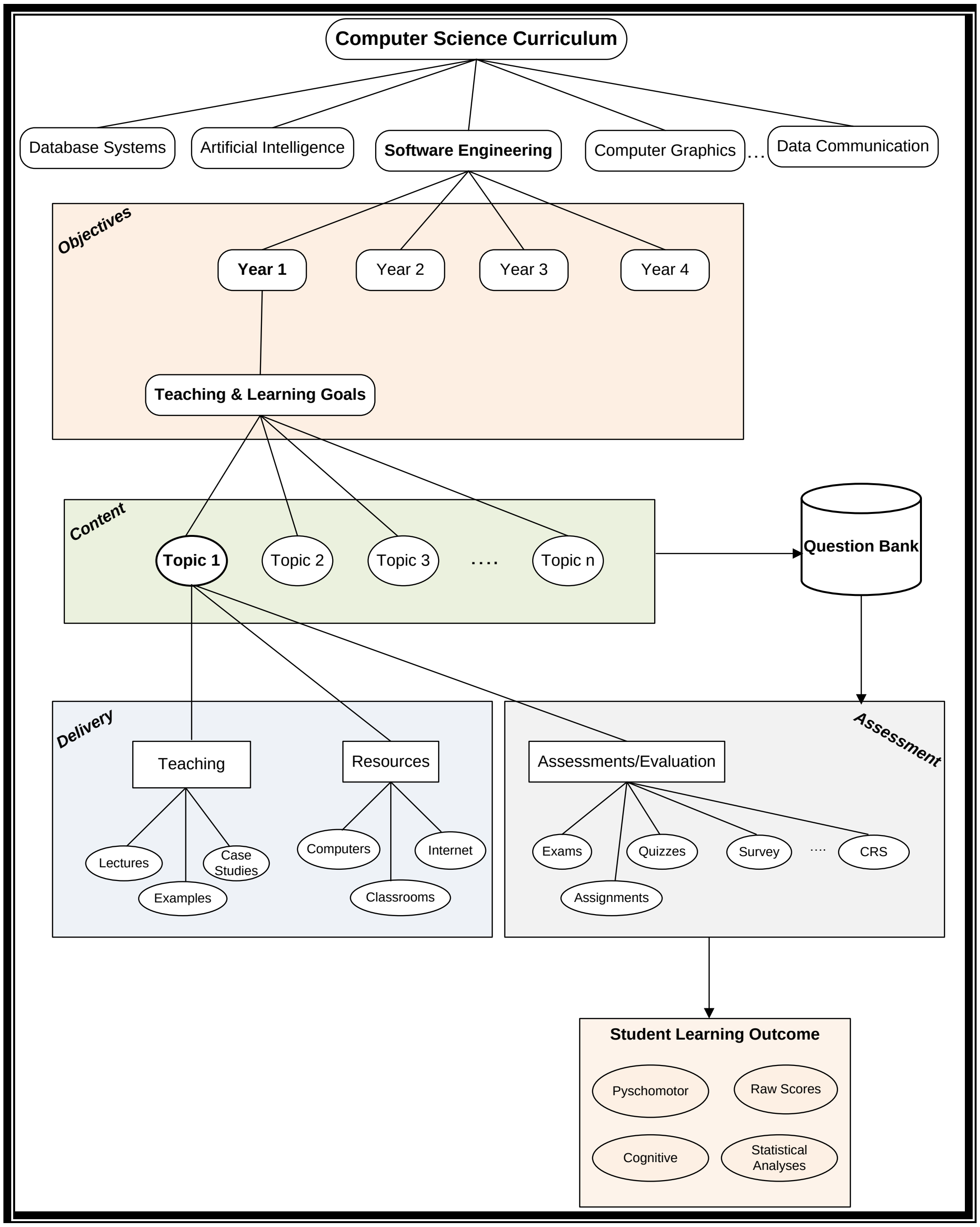


Figure 6: Top Level Schema expanded

In terms of the scope of this work, there will not be an implementation of this system in a manner in which one will see it in operation. But rather, as outlined in the schema in figure 6, an attempt will be made to lay the ground work for this new paradigm and to as succinctly as possible make the case for this research.

## 4.1 Designing Curricula to be Context-Aware

Jan Miller in his paper entitled "Computer Science Innovation in Thailand" [6] speaks to an empirical qualitative study of Computer Science education in Thailand. The focus of the study was to determine the diffusion and extent of adoption of the presented technological and educational innovations and to evaluate the Thailand-Australia Science and Engineering Assistance Project (TASEAP) success from the Thai perspective. Interviews from ten computer science departments were analyzed in relation to computer science technologies, teaching methods, innovation diffusion and adoption, organizational culture, systems success and national cultural behavior [6]. Much of this study paid close attention to the higher educational developments, economic and technological environments and conditions that were taking place in Thailand at the time. The outcomes and the evaluations of the project were also done from a Thai perspective.

TASEAP focused on teaching and research methods, curriculum development, the use of technology such as the internet for teaching, specialist discipline skills, and laboratory, school and faculty management. The reason for highlighting this research here is to bring across the point that curriculum development and innovation is influenced by many factors including cultural context and sensitivity. For instance, a culture where internet usage and adoption is very high will work well for a curriculum that is heavily biased towards distance learning, but would not be well suited for a country that has limited internet availability. Hence there is the need for a framework in which the development of a curriculum can seamlessly accommodate such cultural differences and diversities without negatively affecting the standard and quality of said curriculum. A curriculum developed and utilized in Thailand may work well in a Thailand setting, but may not work well in the United States for instance. So even though certain features may be different such as the delivery, resources and so on, the quality, standard and overall effect must be similar so that regardless of which ever territory the curriculum is, its uniformity can be guaranteed. So the bottom line is that in designing a curriculum, context sensitivity such as culture, the stakeholders and needs must in some way be taken into consideration. Again, it must be highlighted that the illustration in figure 7 is really the essence of this new paradigm. A paradigm which allows a curriculum to seamlessly and easily capture the needs of its audience, the culture of the target population and the resources that are available to deliver said curriculum

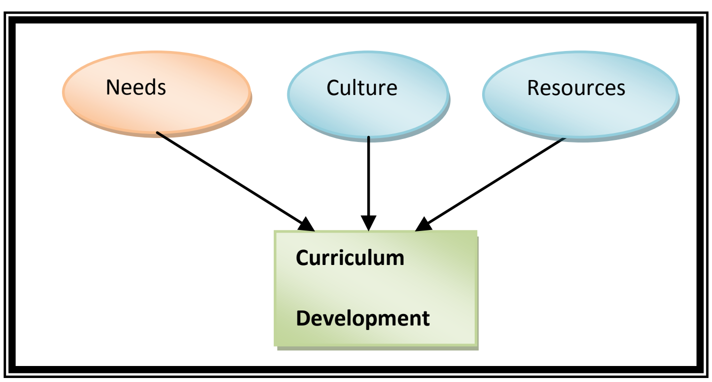


Figure 7 – Considerations that feed into a curriculum design

## 4.2 Starting Point

Richard Gluga et al. have developed an architecture and a tool called CUSP (Course and Unit of Study Portal) [10] that serves a curriculum information tracking system which facilitates the systematic tracking of skill and competence level progression in a Computer Science context. The issue of effectively modeling curriculum skills, mapping them to assessment tasks across subjects of a degree, and measuring the progression in learner competence level is seen as an unsolved problem for the most part. A system called ProGoSs is also utilized in [8] which is under active development. ProGoSs engrains Bloom's Taxonomy which is particularly important since Bloom plays a key role in defining curricula like the current ACM/IEEE-CS curriculum guidelines.

| Professional Practice | | | |
|---|---|---|---|
| **TOPIC** | **YEARS** | **DEPTH** | **RATIONALE** |
| PRF.psy | 1 to 4 | 15% | # 5 & #6 be change from K to C->"DEALING" is not merely KNOWING. Dealing needs to provide course of actions to certain issues e.g. forecasting, predicting, identifying, presenting alternative solutions. All items are ESSENTIAL |
| PRF.com | 1 to 4 | 40% | All items are ESSENTIAL |
| PRF.pr | 1 & 4 | 45% | All items are ESSENTIAL |
| **Software Management** | | | |
| **TOPIC** | **YEARS** | **DEPTH** | **RATIONALE** |
| MGT.con | 2 to 4 | 10% | All items are ESSENTIAL |
| MGT.pp | 2 to 4 | 31% | All items are ESSENTIAL |
| MGT.per | 2 to 4 | 11% | All items are ESSENTIAL |
| MGT.ctl | 2 to 4 | 21% | All items are ESSENTIAL #5 & #6 be change from O to E and classified as K->to achieve quality performance/output would require effective supervision/management |
| MGT.cm | 2 to 4 | 27% | All items are ESSENTIAL #7 be change from D to E and classified as A->Security is an essential part of software configuration management. Topic #7 must be renamed as Distribution, Back-up, and Security. #4 be change from C to K->BUILDS deals more on conceptual/theoretical rather than actual application in the classroom set-up |

Table 1: Sample workshop output table [9]

In [9], the IEEE-CS/ACM SE document was used as the main input source for a workshop to identify a set of topics for teaching software engineering across the four years of an undergraduate program. This workshop was a step towards the establishment of a proposed repository that will serve as a tool to enhance the teaching and learning of Software Engineering in an international environment. Table 1 shows a sample workshop table that resulted from the efforts in [9]. It shows the recommendations for the year/s in which each topic should be taught, the depth at which they should be, as well as a rationale for each of the attributes ascribed to each topic. The work done in [8] will serve as a foundation in this work with the guidelines in [8] being an important contributing component.

## 4.3 Future Work

This paper lays the foundation for what promises to be an innovative new direction in the curriculum design process. Implementing a paradigm of this nature will take much effort and time, but it is clear to see the potential long term benefits. The future work will involve using software engineering as a case study by taking an input source much like the output from the workshops in [9] and modeling it in the proposed framework. Designing a suitable template for this model, database design and front-end interface are all considerations for future work. The architectural platform for the system will be Cloud along with associated computing technologies [11] to enable greater accessibility and international collaboration.

# 5 Conclusion

The preliminary outlook into this work seems very promising and there is a clear need for a work of this nature. Curricula are a critical component in the educational system and the overall teaching and learning experience. By capitalizing on the use of technology in this activity in a holistic way, there will be benefits for all stakeholders. The timeframe needed and the major milestones to be achieved are not yet very defined. Still, there are many components to this paradigm and the scaling of it may result in other researches being spawned.

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