AC 2008-1581: A COURSE SEQUENCE FOR INTEGRATING PROBLEM SOLVING AND CRITICAL THINKING IN A HYBRID OUTCOME-BASED IS/IT CURRICULUM

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A Course Sequence for Integrating Problem Solving and Critical Thinking in a Hybrid Outcome-Based IS/IT Curriculum

Abstract

In this paper we propose a curriculum for the information systems (IS) and information technology (IT) fields that follows the ABET criteria and the IS 2002 recommendations. The proposed curriculum is driven by two sets of learning outcomes: the university learning outcomes, which are a set of higher level outcomes and the college learning outcomes which are embedded in all core courses. A course sequence was developed to facilitate student learning of problem solving and programming concepts. The sequence includes courses in problem solving, algorithm design and development, solution modeling and coding. VB.Net, a visual programming environment, was the language of choice to introduce object oriented programming. The master course syllabi for the sequence provide clear details about learning outcomes covered in that course as well as the piece of evidence for that outcome. The master course syllabi with clearly defined learning outcomes can help instructors focus their lessons. The proposed course sequence can help students learn problem solving concepts naturally and facilitate the programming learning process. It is anticipated that such a curriculum will reduce students’ fear of programming and renew their interest in the computing field in general as well as the IS/IT field in particular.

Introduction

Academic institutions in the US and elsewhere aspire to generate an IS/IT curriculum that can produce graduates with critical skills required by business and government as well as provide the needed general education. Currently, the IS 2002 recommendations form the blueprint for curriculum development of IS majors. An important part of the IS curriculum is problem solving and programming. As a matter of fact the IS 2002 recommendations not only acknowledge the importance of problem solving in the curriculum but it requires an embedded approach to introducing problem solving in all core courses. Many students however still encounter difficulties in understanding the concepts of programming. These difficulties become more pronounced when students attempt to use the syntax and semantics of a programming language and develop real world applications.

Colleges and universities worldwide use various approaches to teach problem solving and programming. There is, however, disagreement on how to integrate problem solving and critical thinking in IS/IT courses. In fact only a few IS/IT courses touch upon the topic of problem solving. Furthermore, there is no standard approach to integrating concepts in problem solving as a whole. Most courses which claim to introduce problem solving mainly focus on programming concepts. These courses seem to be challenging to most students and as a consequence, after taking these courses many students change their major. This has created a difficult situation for IT colleges as the number of entering students, particularly females, continues to drop. Most faculty members believe that the issue lies in choosing the appropriate programming language. This has prompted a number of colleges to focus on the programming languages that need to be
taught in various courses. Currently, the most popular languages include: C++, C# and Java. These have become the programming languages of choice for academia and industry. Most institutions that adopted Java have done so because Java is platform independent. However, Java is not easy to learn even for non-novice programmers.

Zayed University (ZU) is an all female academic institution in the UAE that has established an IT program to satisfy the needs of the country as well as the ABET accreditation requirements. The IT curriculum is driven by two sets of learning outcomes; the university and the college learning outcomes. The curriculum has 126 semester credit hours, including 60 semester hours in General Education. The IT curriculum provides the opportunity for students to pursue three specializations: Web Technologies, Networks and Telecommunication and Information Security. Critical thinking and reasoning is an important university learning outcome that has to be implemented in most courses. Another learning outcome that is specific to the College of Information Technology is problem solving. The core component of the IT curriculum offers a sequence of courses in problem solving and programming. The IT curriculum has gone through a number of rounds of updates and changes. The goal of these updates was to provide a curriculum that fulfills the needs of government and business in the country. However, the curriculum was perceived to be difficult by students because there were too many programming courses.

In this paper, we propose a course sequence that emphasizes problem solving in the Web Technologies curriculum courses prior to introducing the syntax and semantics of a programming language. The proposed sequence includes courses in problem solving concepts, algorithm design and development, solution modeling and finally coding. The rest of the paper is organized as follows: Section 2 introduces the University and IT College learning outcomes, Section 3 shows details of the IT curriculum at Zayed University, Section 4 lists the IS 2002 recommendations and ABET criteria, Section 5 presents the proposed course sequence for embedding problem solving and critical thinking learning outcomes, and Section 6 is the conclusion.

The university and IT College learning outcomes

Zayed University (ZU) is an educational institution in the UAE that adopted a hybrid outcome-based and grade point average academic model that provides students with an education of lasting value and makes them become self-learners. This academic program model (APM) is designed to continuously improve the curriculum and provide students with the knowledge and skills in a rapidly growing country. The learning outcomes, being the kernels of the courses, provide focus to the curriculum in the APM. Furthermore, all courses are designed to clearly show the experiences that students draw upon while achieving particular learning outcomes.

There are six ZU Learning Outcomes (ZULOs), which are the over-arching requirements for students to graduate from their major. ZULOs identify five critical areas, which are significant for students. These are: Critical Thinking and Reasoning, Information Literacy and Communication, Information Technology, Global Awareness, Teamwork, and Leadership. During their last semester students need to participate in the internship program and complete a capstone project.
The ZULOs, which form the framework for the APM, are designed to help students develop higher order intellectual abilities needed for lifelong learning and success. All students must demonstrate accomplishments in the following ZULOs before they graduate:

- **Information Literacy and Communication (ILC):** Students who graduate will be able to recognize information needs, access and evaluate appropriate information to answer those needs, and communicate effectively to a variety of audiences in English and Arabic.
- **Information Technology (IT):** Graduates will be able to use information technology to solve problems and communicate in an ethical way. They will also be critically aware of the impact of information technology on the individual and society.
- **Critical Thinking and Reasoning (CTR):** Graduates will be able to use information, reasoning, and creative processes to achieve goals and make responsible decisions.
- **Global Awareness (GA):** Graduates will be able to relate to communities beyond the local, perceive and react to differences from an informed and reasoned point of view, and be critically aware of implications and benefits of cultural interactions.
- **Teamwork (T):** Graduates will be able to work efficiently and effectively in a group.
- **Leadership (L):** Graduates will be able to assume leadership roles and responsibilities in a variety of life situations and accept accountability for the results.

The College of Information Technology (formerly called College of Information Systems) at ZU seeks to produce graduates who have an understanding of information technology and it uses and who are capable of identifying and solving problems. The College of Information Technology has established five learning outcomes that complement the learning outcomes of the ZU APM. These Major Learning Outcomes form the basis for analysis and assessment that play an essential role in the continuous process of improvement. The Major Learning Outcomes for the College of Information Technology are as follows:

- **Problem Identification and Analysis:** Ability to define a problem and to effectively analyze factors relative to its solution
- **Problem Solving:** Ability to derive and evaluate solutions to problems
- **Information Technologies and their Applications:** Understanding of theory and application of information technologies and ability to use information technology effectively to derive solutions to problems
- **Systems Theory and Practice:** Understanding of systems principles and applications
- **Technical Communications:** Ability to evaluate, organize, develop, and present written and oral technical material

The IT curriculum includes courses in the following knowledge domains:

- General Introductory/Computer Literacy/Professional issues
- Computing Foundation
- Programming and Problem Solving Foundations
- Database Management
The IT curriculum and problem solving and programming courses

The current IT curriculum includes a sequence of courses to teach programming and problem solving at various levels of the curriculum. The sequence includes the following required courses:

- CIT 210 Introduction to Computer Information Systems
- CIT 215 Computing Foundation
- CIT 225 Programming and Problem Solving I
- CIT 245 Web Programming
- CIT 320 Programming and Problem Solving II
- CIT 365 Database Systems
- CIT 440 Enterprise Web applications
- CIT 460 Systems Analysis and Design

The electives are given below:

- CIT 325 Applied Object Oriented Programming
- CIT 475 IT Systems Development

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<tr>
<th>Semester 1</th>
<th>Credits</th>
<th>Semester 2</th>
<th>Credits</th>
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<tr>
<td>Year 1</td>
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<tr>
<td><strong>COL 110</strong> Computer Applications</td>
<td>3</td>
<td><strong>COL 105</strong> Career Exploration</td>
<td>2</td>
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<tr>
<td>COL 120 Colloquium</td>
<td>3</td>
<td><strong>COL 111</strong> Explorations in Mathematics</td>
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<td>COL 130 Arabic Concepts</td>
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<td><strong>CIT 125</strong> Discovering IT</td>
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<td>COL 140 English Composition I</td>
<td>3</td>
<td>Menu I Comparative Professional Systems</td>
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<td>COL 150 Global Studies I</td>
<td>3</td>
<td><strong>COL 135</strong> Islamic Civilization I</td>
<td>3</td>
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<td><strong>Total</strong></td>
<td><strong>15</strong></td>
<td><strong>Total</strong></td>
<td><strong>18</strong></td>
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| Year 2                              |         |                                   |         |
| **CIT 210** Intro. to IT and Info. Systems | 3     | **CIT 215** Computing Foundations | 3       |
| COL 230 Islamic Civilization II     | 3       | **CIT 225** Intro to Programming/ Problem Solving | 3     |
| COL 240 English Composition III     | 3       | **CIT 235** Information Security Basics | 3     |
| COL 250 Global Studies II           | 3       | **CIT245** Web Development         | 3       |
| COL 260 Environmental Science       | 3       | **CIT 255** Networks & Telecommunications | 3     |
| **Total**                           | **15**  | **Total**                          | **15**  |

| Year                                 |         |                                   |         |
| **CIT 300** Technical Writing (English) | 3 | **CIT 305** IT in Global/Local Cultures | 3     |
| **CIT 301** Technical Writing (Arabic) | 2 | **CIT 306** IT in Global/Local Cultures | 3     |
| **CIT 320** Programming & Problem Solving | 3 | **CIT 325** Applied Programming    | 3      |
Figure 1. Eight semesters IT Curriculum showing the courses that provides an opportunity to include problem solving.

Figure 1 shows the list of courses in problem solving and programming (in bold). During their first year, students learn COL 110 and CIT125. In Year Two, students take four courses; CIT210, CIT215, CIT225, and CIT245. In Year Three, students need to take two required courses, CIT320 and CIT 365, and one elective, CIS325. In Year four, students need to take two courses; CIT 440 and CIT 460 and one elective; CIT 475.

In CIT 210, students are introduced to computers where they learn about the history of programming languages. In CIT 215 students learn about algorithm design, logic and functions. In CIT225 and CIT320, students are introduced to the concepts of programming and learn about object-oriented programming languages. In CIT245, students are introduced to the principles and tools of web programming. CIT365 introduces students to the fundamental concepts of database systems. Both of CIT325, an advanced course in object-oriented programming, and CIT475, a course in systems development, are electives. However, only CIT 225 and CIT 320 emphasize problem solving as a topic of the course. Moreover, CIT 225 allocates less than half the class time to problem solving and CIT 320 is mostly about programming. It is therefore necessary to introduce problem solving and critical thinking before CIT 225 and also after CIT 320.

There are a number of issues and challenges in designing and implementing IS/IT curricula. One of these issues is the selection of a modern appropriate programming language that fulfills the requirements of the ABET criteria as well as the IS 2002 recommendations. ABET requires the student to be proficient in a modern programming language. The IS 2002 recommendations include only one course in programming which is not enough for students to master a programming language. To become proficient in a modern programming language, students must take at least two courses in problem solving and programming. When it comes to advantages and disadvantages of conventional programming languages such as C, C++, and Java, programmers usually hold strong opinions. An elaborate comparative analysis is needed to draw conclusive results. Despite obvious difficulties in conducting such analysis, we still need to compare different programming languages for further insights. Acquiring such knowledge will help improve curriculum design and may help advance the state of software development.
**IS 2002 recommendations and ABET criteria**

For the development of the IT curriculum, the IS 2002 recommendations were followed. This model curriculum was chosen because most graduates join the IS field. The characteristics of the IS profession were identified and listed in the recommendations:

- IS professionals must have a broad business and real world perspective
- IS professionals must have strong analytical and critical thinking skills
- IS professionals must have interpersonal communication and team skills and have strong ethical principles
- IS professionals must design and implement information technology solutions that enhance organizational performance.

The curriculum has 30 semester credit hours of formal IS courses but also use of prerequisite courses in: Communications, mathematics, statistics and business functions. The IS 2002 model curriculum also requires an embedded problem solving and critical thinking framework in all courses. The architecture of the IS model curriculum consists of five presentation areas:

- Information systems fundamentals
- Information systems theory and practice
- Information technology
- Information systems development
- Information systems deployment and management processes

The five presentation areas consist of ten courses and one prerequisite. They are:

- IS 2002.P0 - Personal Productivity with IS Technology
- IS 2002.1 - Fundamentals of Information Systems
- IS 2002.3 - Information Systems Theory and Practice
- IS 2002.4 - Information Technology Hardware and Systems Software
- IS 2002.5 – Programming, Data, File and Object Structures
- IS 2002.6 – Networks and Telecommunication
- IS 2002.7 – Analysis and Logical Design
- IS 2002.8 – Physical Design and Implementation with DBMS
- IS 2002.9 - Physical Design and Implementation in emerging Environments
- IS 2002.10 - Project Management and Practice

The ABET criteria are that at least 30 semester credit hours of IS must be included in the IS curriculum. Using the IS 2002 model curriculum and ABET criteria for accreditation as a basis, a course sequence which integrates problem solving and critical thinking was developed. The course sequence was also designed to facilitate the student learning of difficult concepts in programming. VB.Net, a modern object oriented programming language was selected because of its ease of use and popularity with students.

**Course sequence for embedding problem solving learning outcomes**

A course sequence is proposed for introducing problem solving and critical thinking concepts across the curriculum. These concepts are introduced in early courses such as CIT 210 and CIT 215 and become more advanced in 300 and 400 level courses such as CIT 325 and CIT 475.
In the first year of the IT/Web Technologies curriculum students learn how to use productivity tools to solve real-world problems. This is the first exposure students have to the concepts of problem solving. In the second year of the IS curriculum, students learn programming methodology and how to solve a problem without using a particular programming language. Students learn how to create applications using Visual Basic.NET programming language which has become popular among students. They also learn web programming which includes HTML and XML. In the third year of the IS curriculum, students learn programming and problem solving again using VB.Net at a higher level. Here, students learn advanced concepts of object-oriented programming and IT hardware and software while staying focused on problem solving. The elective courses provide an opportunity for students to learn Java, an alternative programming language and/or learn about software engineering using the Unified Language Modeling (UML). In total, students spend 30 semester hours between their freshman and junior years learning problem solving concepts and programming.

The course sequence as shown in figure 2 will help instructors to not only cover the course material but also to focus the course by including opportunities for learning problem solving and/or critical thinking concepts. These two learning outcomes are clearly listed in the master course syllabi of a number of courses. The gradual exposure to these two outcomes can help students learn programming with much less difficulty. Visual Basic.Net was the preferred language by many students as opposed to Java or C++. Therefore, it was used in two core programming courses (CIT 225 and CIT 320).

Figure 2 shows the adopted sequence of courses from the second to the fourth year of the curriculum. The levels in problem solving and critical thinking increase with the course content and this is reflected by the change in color in the diagram that lists the sequence. Each course shows the leaning outcome that is associated with it and the master course syllabus clearly identifies that outcome.

The master course syllabus is a critical component of the IT curriculum that addresses the integration of desired learning outcomes into various courses of the curriculum. A master course syllabus was developed for all core and elective courses. The components of the master course syllabus include course number and title, objectives, topics, learning outcomes, and evidence of outcome achievement. The course description is taken from the University course catalogue. The course objectives provide focus on the course content. The course topics are listed in order to provide guidance and allow coverage of critical components of the course. All learning outcomes are listed in a table along with the courses that go with them. Students have the opportunity to select various projects as well as other learning experiences to document their achievements of the College and University learning outcomes in an electronic portfolio. The electronic portfolio has become a critical piece of evidence that demonstrates student learning. Finally, prospective employers seem to prefer to look at the student’s electronic portfolio as it provides a stronger evidence of the student’s abilities to perform a job without further training.
Figure 2. Proposed courses with problem solving and critical thinking components

Conclusions

In this paper two critical components of the computing discipline were examined: problem solving and programming. A course sequence was developed to facilitate student learning of problem solving and gradually introduce programming concepts. Problem solving and critical thinking are first introduced in 200 level courses and become more advanced in 300 and 400 level courses. VB.Net, a visual programming environment, was the chosen language to introduce object oriented programming because of its ease of use. The curriculum in the IT College incorporates learning outcomes that address problem solving and critical thinking at various levels of the students’ learning stages. However, the implementation of the curriculum to take full advantage of these learning outcomes is still at an early stage. Instructors need to rethink their course delivery and redesign their course contents to effectively include problem solving and critical thinking. In the course sequence, problem solving and critical thinking are listed in all master course syllabi as well as the evidence of achievement. The master course syllabus can help instructors focus their courses and design specific learning experiences to facilitate student learning. This approach allows students to learn problem solving concepts naturally as well as programming in later courses. It is anticipated that such an approach will reduce students’ fear of programming and hopefully renew their interest in the computing field.
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