Workshop on Discrete Mathematics for Programs Conforming to ABET Information Systems Accreditation

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Abstract

This workshop provides practical information on how to design and implement a discrete mathematics course for an information systems program seeking ABET accreditation or already accredited by ABET. A matrix correlates the local ABET-accreditable core curriculum with a standard set of discrete mathematics topics to derive relevant topic coverage. Materials, software resources, and teaching techniques are targeted toward needs and interests of IS students and thus foster motivation and confidence as well as understanding of how the concepts presented serve them in learning and will serve them in career settings. The technological and societal reasons for including discrete mathematics in the IS curriculum are covered. Experiences in the information systems (IS) and information systems management (ISM) programs at Robert Morris University (RMU) guided the design of this workshop.

Keywords: discrete mathematics, quantitative analysis, ABET, curriculum

1. INTRODUCTION AND RATIONALE

ABET accreditation criteria for information systems (IS) programs (ABET, 2003) include discrete mathematics in the quantitative analysis specification (ABET IS Standards IV-3, IV-11, IV-13). This workshop responds to the ABET criteria by delivering information on how discrete mathematics can be appropriately presented to information systems students. The relevance of discrete mathematics topics has been well-defined for computing in general and for computer science (ACM/IEEE, 2001; ABET computer science Standard IV-11), but the needs, interests, and ambitions of IS students are different from those of computer science students.

This workshop is designed both to inform and to foster discussion about how to implement discrete mathematics in IS programs and address ABET IS accreditation criteria for quantitative analysis and will provide participants with examples of a design matrix, goals, objectives, and presentation materials. A discrete mathematics course for IS can be implemented in the institution's mathematics department or in the information systems department. In both cases communication and collaboration are necessary to assure that IS program needs are met.

In our experience developing the curriculum for information systems students at Robert Morris University (RMU), we sought to envision the challenges that our IS graduates face now and will face in the future and recognized that preparation in discrete mathematics is essential. As information technologies have grown more complex and information systems more integrated, discrete mathematics provides a formal foundation in understanding the methods in modeling, analysis, specification, design, verification, development, and documentation of information systems. The formal structures of discrete mathematics support initiatives to achieve software reliability, safety, and suitability.

Discrete mathematics offers a formal foundation for concepts and operations covered in core courses of an IS curriculum. Certain discrete mathematics topics provide practical support for problem-solving in various programming courses utilizing specific programming, scripting, and markup languages such as C, C++, COBOL, HTML/XML, Java, M/Caché ObjectScript, and Visual Basic, and for database courses and the teaching of SQL.

At RMU three departments worked together to produce the curriculum recommendations given in this workshop: computer and information systems, mathematics, and engineering (which has a software engineering program). This collaboration acknowledged the shared interest of all three programs in discrete mathematics and assured instruction that benefited from the contributions of each. Collaboration also laid the groundwork for sharing information, faculty, and resources among the programs. It is necessary to have sufficient rigor in the course along with understanding of the ABET standards and the particular needs of information systems students.

2. DETERMINING GOALS, OBJECTIVES, AND TOPICS TO BE COVERED

To begin the design for a discrete mathematics applications course at RMU, a matrix correlation of discrete mathematics topics and IS applications covered in core curriculum courses was reviewed in the RMU Computer and Information Systems Department in the fall semester of 2001. This matrix was designed originally to assess discrete mathematics requirements and content of existing core curriculum courses. The traditional topics of discrete mathematics, as taught for mathematics, computer science, and software engineering, comprise one dimension of the matrix. The other dimension represents the core curriculum courses in an ABET-conformant IS program. In each cell of the matrix is a list of all the "intersection points" of a given discrete mathematics topic with the topics covered in a particular IS core curriculum course, such as database management, data communications and networking, hardware and operating systems, programming in a particular language, programming logic, or network security. The only discrete mathematics topics retained for the IS curriculum design are those relevant for one or more core curriculum courses. This approach makes it possible to give all attention to the relevant topics and omit those not relevant. The resulting list, in our case, is: logic; sets; sequences and strings; number systems and representation of numbers; relations, functions, and operators; randomization, permutations, and combinations, relational database concepts; algorithms; codes, encryption, and compression; graphs and trees; automata and pattern matching; and documentation of computer languages. The matrix guided us in the process of articulating proof of relevance of discrete mathematics topics for our core curriculum.

Through this method the discrete mathematics curriculum for a given IS program can be designed based on the core curriculum adopted for that particular program and thus respond to design decisions of IS faculty throughout the IS department. Design implications derived from the matrix can guide discrete mathematics curriculum development either within the IS department or in interdisciplinary discussions when the discrete mathematics course is to be offered by another department, such as mathematics. A number of information systems programs worldwide have implemented discrete mathematics instruction within the IS program, as RMU has, while others have worked with mathematics departments on the development of suitable courses in mathematics. At RMU the preference was for a course that could be taught by faculty in any of the three collaborating departments and is located in the department teaching information systems courses.

An interdisciplinary committee was established, involving the contributing disciplines of information systems, mathematics, and software engineering, to proceed with development of the course and materials and with planning for sharing of information among the departments and programs. Working together not only fostered sharing of mathematical knowledge, but also of the requirements and needs of IS students. Interdisciplinary context and collaboration strengthened interdepartmental relationships and information exchange and provided a basis for drawing faculty from different departments. Recommendation 4 of the Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America encourages interdisciplinary faculty collaboration in modifying and developing certain mathematics courses. (CUPM, 2004) The collaboration established originally continues in evaluation of the course and materials and in development of papers and reports.

There were questions about whether formal logic notation should be used in a course intended for information systems and information systems management majors. A careful analysis revealed that internationally accepted formal notations made the material clearer and easier to learn. Formal structures represent only part of the task of teaching discrete mathematics. Much of effort involves understanding how logical structures are communicated in everyday natural language. Ambiguities in natural language, as in specifications for applications, systems, and projects, must be addressed. Formal notation is of great practical help in this process of learning about the meanings of specifications. Students readily apply what they have learned using formal notation to such practical concerns as database design, conduct and management of programming in application development, and understanding the properties of data communications networks. We considered how unnecessarily challenging it would be to teach music while avoiding use of internationally accepted music notation. Students relate that their discrete mathematics experience, presented to them using formal notation, helps them comprehend specifications (as they would need to do in the system analysis process in their careers). They report increased correctness and confidence in such tasks.

While we omitted some discrete mathematics topics through the matrix process, in a few cases the result we regarded as appropriate for information systems goes beyond the traditional approach. Our definition of partial order includes coverage of strict partial order rather than just the usual (reflexive) characterization because practical IS examples generally involve strict partial order (such as the order of creating tables and loading data (and inversely of dropping tables) in relational database designs with enforced referential integrity). We also found that a treatment of relations and functions accounting explicitly for source and target sets and clearly distinguishing them from domain and range, as in formal specification, meets IS teaching needs. The distinction between source set and domain has practical implications for the design of relational database queries in database management courses. Input from colleagues in other programs was helpful in evaluating curriculum design choices.

We support learning by giving examples showing the practical importance of discrete mathematics for information technology and business applications (Wildstrom, 2002). In the treatment of codes we included code division multiple access (CDMA), which reveals how the mobile telephone system works, a topic of interest to students.

In order to strengthen the interconnection between topics covered in our discrete mathematics course and the utilization of discrete mathematics in core curriculum courses (such as database management, operating systems, networking and data communications), as revealed in the original matrix, a series of discrete mathematics teaching guides is being developed. Each guide focuses on a single intersection point from the matrix and seeks to provide direct support for learning in a core curriculum course. The first such guide to be completed deals with relational database tables in database management and covers the use of partial order in determining (1) correct ordering in designing and establishing relationships and utilizing referential integrity constraints, (2) correct orders of loading data into tables in accordance with design and referential integrity constraints, and (3) correct orders of dropping tables in revising a database design. The guide incorporates examples of how to apply understanding of partial order to solve a practical problem faced by students loading datasets into databases and sample assignments.

Another guide relating to database management (and its intersection with set theory in our matrix) covers the use of set difference concepts in designing correct exclusionary queries in SQL. The guides underscore relevance at the same time they support problem solving in the core curriculum.

3. SELECTING AND ADAPTING MATERIALS AND RESOURCES FOR IS PROGRAMS

While we found many excellent and popular textbooks for discrete mathematics, those focusing on computer technology are generally directed to a computer science audience (Epp, 2004; Gersting, 2003; Grassman/Tremblay, 1999). A computer science orientation affects not only topic coverage, but also choice of variable names and the choice of examples and exercises. We also looked at Rosen, which is application-oriented and has been adopted for discrete mathematics in a number of information systems or information technology programs (Rosen, 2003). The question arose of how to adapt existing discrete mathematics materials for IS use and to assemble needed supplementary materials. A base text (Johnsonbaugh, 2001) was selected by a faculty committee. Interdisciplinary collaboration led to development of instructional materials and publication of a custom textbook targeted to information systems. This text serves as a supplement to the base text and gives students topics not covered in the base text and also examples relevant for IS (Harvey et al., 2003). Additional supplemental material has been developed or refined every semester and this accumulated new material is provided to the students in hard copy and online.

We focus on practical and application-related examples where possible. Included in our module on sets are Venn diagrams documenting wireless protocols. Graph and tree examples, classified according to type, come from networking and other application domains. Students respond very well to these examples and quickly learn to characterize graphs and to deal with paths and cycles. Coverage of spanning trees is related to IP multicasting and the IEEE 802.1D protocol. Finite state diagrams and the topic of state transitions focus on operating system examples. Set builder notation practice favors examples appropriate for IS students. Problem-solving applications of discrete mathematics are covered. Database management assignment examples are included.

Effective teaching software resources are of great value for IS students studying discrete mathematics. We initiated a systematic search for suitable software. Criteria included: available for online use or available to download without charge or with favorable academic licensing; ease of use, match to the topics presented, feedback, quality of presentation and interaction. The priority for software support is on fundamentals such as logic, sets, and state transitions. We identified software for digital logic (gates and combinatorial circuits), verification of propositional and predicate logic using the "Tarski's World" paradigm, programming in logic (Prolog), sets (practice with Venn diagrams), number conversions between bases, finite automata (Hacker and Sitte, 2002; Rodger, 2004). Thus students practice with the fundamental "building blocks" of both hardware (circuits) and software (state changes). A detailed listing of online resources is provided to IS students in the discrete mathematics course on a web page so students can link directly to the download sites or interactive exercises. Experience has shown that appropriate interactive software is very effective in facilitating the learning process. In some cases students frequently request additional assignments involving the software or go beyond the assignments. Interactive software demonstrations are important to the process of introducing topics in the classroom.

4. TEACHING STRATEGIES AND TECHNIQUES

The course described in this workshop sets a priority on discrete mathematics topics which are most important and valuable for our students. The discrete mathematics for information systems professionals course gains from clear connections to applications in the core courses of our undergraduate curriculum. The most important goals to keep in mind in design and implementation of this course are (1) help students recall, adapt, and reuse the formal knowledge they bring with them to this course and to the entire curriculum, and (2) provide students with opportunities to develop and demonstrate practical examples of how the concepts being treated are used in information technology. General "big picture" topics include the role of proofs and verification in software development, the importance of correct logical interpretation in application development in business, industry, and the public sector, and the significance of invariants.

The introduction to a course of this type should include a review of algebra, with a focus on those properties of algebraic notation most useful in logic notation and Boolean algebra: order of precedence and evaluation of expressions, and also of matrices, useful in the representation of graphs. The treatment of expressions, and also laws, such as commutivity, in grade school arithmetic, algebra, and logic, are compared. The material in the course is designed to support a variety of levels of interest and involvement, from basic to advanced to honors.

For students who select this course early in their sequence of enrollment, it should provide context for certain technical portions of courses taken subsequently. The discrete mathematics text will then be available to supplement regular texts in operating systems, databases, networking, etc. This material should augment and support what is in the current texts for the various core courses and give the student an important resource.

For students who enroll in this course later in the sequence, it should serve as a review and augmentation of what they have already covered. The course should be presented in a manner that will provide effective support for the student's progress in either situation. The more advanced students may serve as resources for the others.

5. OUTCOMES ASSESSMENT

Logic is a key part of discrete mathematics. With regard to discrete mathematics courses in ABET-accredited programs, the "Propositional Logic Test (PLT) can be used for outcomes assessment. The PLT, developed and used over a number of years by science education faculty and students at Rutgers University, assesses an individual's ability to process propositional statements. The PLT is a timed task in which the individual interprets truth-functional operations by identifying instances that are consistent or inconsistent with a stated rule… ." (Almstrum).

Now that the teaching approach described in this workshop has been in place for over a year, a number of assessment techniques have been developed for particular topics in this curriculum. These will be available to workshop participants.

6. CONCLUSION

Appropriate discrete mathematics instruction enhances information systems education by providing a sound formal foundation for and insights into an increasingly complex information technology, helping students recognize and use practical problem-solving tools, and giving information systems professionals insights useful in making management decisions with regard to applications of formal structures in business and industry. This instruction supports the capability of information systems professionals to contribute to software reliability, safety, and suitability in information technology. Planned projects at RMU include developing a textbook which consolidates current materials and which benefits from experience, contributing to automating the PLT to support assessment, identifying or developing additional instructional software for discrete mathematics, and defining learning units for discrete mathematics.

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8. REFERENCES

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ISECON Workshop on Discrete Mathematics for Programs Conforming to ABET Information Systems Accreditation

Time	Topic	Presenters	Handouts
10 minutes	I. Introduction	Valerie Harvey	Workshop Paper (White)
	A. Workshop Team	Valerie Harvey	Bios (Blue)
	B. RMU	John Turchek	Notes (Lt. Green)
	C. CIS Dept	John Turchek	Notes (Lt. Green)
10 minutes	II. Discrete math requirements in the context of ABET Information Systems accreditation	John Turchek	
	A. IS 2002	John Turchek	Notes (Lt. Green)
	B. ABET Criteria	John Turchek	Notes (Lt. Green)
30 minutes	III. Discrete Math experience at RMU	John Turchek	
	A. 1974-2001 a. Separate QS courses b. Integration of discrete math concepts into I/S courses	John Turchek	Notes (Lt. Green) Current Integration Example (Partial Order in Databases; Salmon)
	B. 2001 Initial "DM Integration" matrix review and Discrete Math Plan for INFS3450	Valerie Harvey	Initial Discrete Math Matrix (Orange) and Notes (Goldenrod)
25 minutes	IV. Discrete Math Matrix tied to IS- 2002 and ABET I/S Accreditation Criteria – Discussion, Design	Valerie Harvey and Peter Wu	ABET-IS 2002 Generic Matrix (Orchid) and Blank Matrix (Celery)
35 minutes	V. Sample INFS3450 Discrete Math assignments that may be also utilized in other Information Systems courses – Discussion, Participants' Programs	Valerie Harvey and Peter Wu	INFS3450 Supplement (Ivory)
40 minutes	VI. Software and materials to support Discrete Math instruction – Demonstrations and Discussion	Valerie Harvey and Peter Wu	INFS3450 Supplement (Ivory)
20 minutes	VII. Assessment tools for Discrete Math courses and modules	Valerie Harvey and Peter Wu	PLT Information (Almstrum; Cherry)
10 minutes	VIII. Closing Activities	Valerie Harvey, Peter Wu, and John Turchek	