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Title: The Use and Evaluation of Three Mathematics Subject Classifications by Mathematics Professors: A Grounded Theory Study

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Thesis Advisor

This information user study questions mathematics professors about the usefulness of three mathematics subject classification schemes when performing research. The researcher asked the participants questions about the Library of Congress Classification, Dewey Decimal Classification, and American Mathematical Society Mathematics Subject Classification. The eight participants, identified by a group of contact persons at three Midwestern public universities, were chosen based on representation of mathematical expertise, interest by the participants in this study, and the researcher's access to the participants.

The participants were interviewed and surveyed about the accuracy of knowledge structure, level of detail, and usefulness of the notation of each of the three classification schemes. The interview transcriptions were analyzed using an analytic-inductive process inspired by grounded theory techniques. The survey, using a Likert scale to quantify responses, was analyzed using spreadsheet software. Data from interviews and surveys were used to create a rich picture of the mathematics professors' perceptions of the usefulness of the three classification schemes.

THE USE AND EVALUATION OF THREE MATHEMATICS SUBJECT CLASSIFICATIONS BY MATHEMATICS PROFESSORS: A GROUNDED THEORY STUDY

A Thesis

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by

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CHAPTER 1

INTRODUCTION

This thesis is an information user study of mathematics professors who currently perform research in one or more fields within mathematics. The purpose of this study is to identify strong and weak characteristics of mathematics subject classifications, specifically the Library of Congress Classification (LCC), the Dewey Decimal Classification (DDC), and the American Mathematical Society Mathematics Subject Classification (MSC). The results of this study may be of use to designers of the above mathematics subject classifications, as well as to designers of other mathematics subject classifications. The results will also be of use to academic librarians, especially those who regularly assist mathematics professors, and those who share overall responsibility for policies and practices that are established and implemented by librarians regarding the creation, organization, use, and knowledge contained within libraries. Finally, the research may be helpful to mathematicians who may ultimately benefit from better, more useful classification schemes.

Literature Review

Robert S. Taylor (1966) suggests a definition of information science that Rubin (2004) breaks into four main ideas: (a) information science concerns itself with the phenomenon of information, regardless of type of information package; (b) information science concerns itself with the entire information cycle; (c) the field is interdisciplinary; and (d) that information science concerns the accessibility and usability of information. While this research study touches on all four of these aspects in some way, it is the fourth of these aspects that is most central to this research. Subject classifications, the library tools under examination in this study, are a means for users and librarians to access information, whether searching for monographs, journals, online databases, or other means. More specifically, this study investigates the users of mathematics subject classifications by identifying how useful these tools are to mathematics professors at three Midwestern, public universities. In that vein, this literature review examines three concepts: (a) the value of classification to society, (b) the value of library and information science research to the field of mathematics, and (c) criteria that experts have suggested to evaluate and characterize classification schemes.

Value of Classification

According to Vickery (1975), the value of classification is nearly universal in the field of information storage and retrieval. When comparing to simple alphabetization, classification is a precision instrument to aid in the search for information. When a user needs more than a simple list of names or titles, a classification is often the solution to the problem. Vickery (p. 5) continues in saying that the value of classifications "is established both by logic and by their use in practice." Vickery also recognizes the value of browsing; library users want to find books or other media on similar subjects in close proximity to one another. He goes on to identify two basic characteristics of classification ordering for the purposes of retrieval: (a) that classifications group topics and (b) that classifications sequence topics. Finally, Vickery identifies four main uses of classifications for retrieval: (a) arrangement of books on shelves, (b) for use in subject bibliographies, (c) for use in the creation of alphabetical indexes, and (d) for use in developing successful post-coordinate searching by showing relationships between possible search terms.

Bowker and Star (1999), in their monograph on classification, conclude the text with a chapter simply titled "Why Classifications Matter." They state that classifications are powerful technologies with important ethical and political ramifications. They continue by stating that there is no such thing as an unambiguous, uniform classification system. Bowker and Star also emphasize the mutual presence of classifiers and constituents in the development of classifications, while also cautioning that populist agenda in the development of classifications is also not an unmitigated good.

Importance of LIS Research to Mathematics Experts

In a 1990 survey by Anderson and Rovnyak (1991), one question asks mathematics librarians and mathematics library users to identify several important qualities of the best mathematics academic libraries. The responses were grouped in themes, and the theme "Ease of use, access for browsing, current journal display, organization and arrangement of books, hours open" (Anderson & Rovnyak, p. 1260) was the leading response in a category of themes relating to the library environment. This thesis is couched in the aspect relating to the organization and arrangement of media. The Anderson and Rovnyak survey results also put forth a picture of academic mathematics libraries in the United States, offering statistics on location, size, and other characteristics of such libraries.

A 1993 monograph by Anderson and Pousch, while mostly a bibliography of items for mathematics libraries, offers in its opening pages a guide to the administration of mathematics libraries. In the section concerning bibliographic control, Anderson and Pousch identify inadequacies in the DDC, partly due to the nature of its notation. Anderson and Pousch also mention several authors in the 1970's that suggest methods to improve classifications to best meet the combination of needs of both mathematics patrons and classifiers, including a hybrid notation between DDC and MSC . Anderson and Pousch continue, saying that librarians have not followed up on possibilities for improvement.

The Role of Library and Information Science User Studies

McIlwaine (1997) mentions the need of consultation between user groups and those who design classifications. McIlwaine identifies that user groups do meet with authors of the classifications more frequently than in the past and that authors of the classifications are prepared to listen to suggestions from users. McIlwaine states that editors of the DDC have increased the use of local expertise in the development of schedules covering those regions. Examples of this include the use of local expertise for schedules concerning Japan in the 20th edition of DDC and similarly for New Zealand in the 21st edition. Also, McIlwaine mentions that the Library of Congress, noting that many other libraries use its classification and subject headings, has made adjustments to its structure based on the needs of others. One example McIlwaine gives is the 1991 Subject Subdivision Conference in which experts made suggestions to the Library of Congress Subject Headings.

Kuhlthau (2005) states that collaboration between branches of library and information science (LIS) has been problematic and that a conceptual framework for collaboration is needed. Kuhlthau describes four imperatives towards building such a conceptual framework for LIS. These are:

1. Stay with a problem long enough to verify findings and draw concepts from the findings.

2. Apply the broad conceptual framework of library and information science to inform the findings of our studies.

3. Develop research projects that incorporate concepts of interest to more than one area of the field.

4. Design application of the concepts for implementation into systems and services. (Kuhlthau, ¶ 3)

In elaborating on the third imperative, Kuhlthau specifically points to information user studies as an area that could benefit from collaboration with other areas within library science. This study of mathematics professors as users of classification schemes responds to Kuhlthau's call for research that incorporates concepts of interest to more than one area of the field--in this case, for better subject classifications.

Evaluating Classifications

Ernest Richardson (1935) describes five criteria of a "good classification for books." The five criteria are:

1. It should follow as nearly as possible the order of things....
2. It should be carried out in minute detail.
3. It should be provided with a notation which will allow for indefinite subdivision, using mixed symbols, but with a predominant decimal base.
4. It should be provided with a detailed and specific index.
5. The value of such a system is increased in direct ratio to the generalness of its use. (Richardson, p. 41)

The first three of Richardson's criteria, with some minor modification, are the same criteria investigated in this study: structure, detail, and notation. Richardson's fourth and fifth criteria are outside of the scope of this study but offer excellent options for an extension of the research. When describing the first of his criteria, Richardson continues, saying, “A properly classified library is perhaps the nearest thing that there is to a microcosm.” In this vein, the first of the three criteria of this study seeks to interpret the accuracy of the knowledge structures as perceived by experts in the mathematics field, the participants.

About detail, Foskett (1982, p. 25) states, “The higher the detail, the more likely we are to be able to achieve high relevance…” Foskett’s statement is in relation to information retrieval in a general sense, but also applies to the realm of classification. Foskett then describes detail as, “The extent to which the system permits us to be precise when specifying the subject of a document we are processing.” Including detail as one of the criteria in this study, the participants were asked to provide their perceptions on the appropriateness of level of detail of the classifications.

Sayers (1955, p. 81) writes about notation, “It may consist of any symbols that are capable of marking all parts of the scheme. It should, however, (a) be brief, (b) simple, (c) flexible, and (d) mnemonic.” Sayers continues in noting that flexibility, which is the ability to permit the insertion of new topics in the classification, is the most important requirement of notation. Sayers also identifies the concept of pure notation, in which a classification uses a notation that has only one type of symbol instead of a combination.

Vickery (1975) emphasizes the importance of brief and simple notation. The advantages of brevity, Vickery states, are self-evident. The advantage of simplicity is in the familiarity of symbols and the ease by which symbols can be put in a recognizable order.

Foskett (1982) describes several characteristics of classification notation. Among these are memorability, brevity, hospitality, and expressiveness. Hospitality, similar to Sayer's (1955) concept of flexibility, refers to the ability to insert new topics and notation into the classification. Expressiveness refers to the extent that the notation reflects the nature of the classification scheme.

Iyer and Giguere (1995) contend that various mathematics classifications schemes differ in four broad ways: structural, semantic, lexical, and notational features. They suggest, more specifically, that some of the variations include differences in subject domain, scope, level of specificity, terminology, or even spelling. In understanding this difference, Iyer and Giguere suggest the possibility of software that easily could map one mathematics classification to another. For example, DDC 514.3 covers the same topic as MSC section 54, general topology. The article presents prototype designs towards the development of such a scheme.

Overview of Classifications in this Study

LCC

In 1815 Thomas Jefferson sold his personal library to Congress. With the book collection came the classification system that Jefferson developed. This classification, based on schemes by Francis Bacon and Jean le Rond d'Alembert, continued in use by the Library of Congress until the turn of the 20th century, when the Library of Congress collection had grown too large for Jefferson's classification to be effective (Foskett, 1982).

The Library of Congress seriously considered three classifications as a replacement for Jefferson's scheme: the Decimal Classification, by Dewey; the

Expansive Classification, by Charles Cutter; and the Halle Schema, by Otto Hartwig (Chan, 1999). After much consideration, the Library of Congress chose Cutter's classification, but also recognized a need to change the notation portion of the classification. James Hanson, Head of the Catalogue Division, was the primary person in charge of developing the classification for the Library of Congress. Hanson suggested the new outline of classes in 1899 and suggested other revisions in 1903 and 1904 (Chan). With the help of subject specialists, the Library of Congress published the first of the new classification schedules in 1901, Class E-F (American history), followed by Class Z (Bibliography, library science) in 1902. Many others were completed by 1904 (Chan).

Unlike the DDC, whose editions are published as a four volume set, the LCC contains many more volumes, or schedules, each of which is updated individually. The Library of Congress first published the schedule for Class Q in 1905. They published the most recent edition, the ninth, in 2004 (Library of Congress Cataloging and Support Office, 2004). Class Q, titled "Science," contains the mathematics classification excerpts used in this study. More specifically, mathematics is Subclass QA with the remainder of Class Q devoted to other science topics such as physics, botany, and microbiology. Each LCC notation in mathematics begins with the letters QA.

The Cataloging Policy and Support Office of the Library of Congress (CPSO) edits the classification, considering new additions, changes, and deletions, based on literary warrant. The CPSO notices trends in the subject of materials received by the Library of Congress and makes modifications. Modifications are also suggested through the Subject Authority Cooperative Program (Library of Congress, Program for Cooperative Cataloging, 2006), which allows libraries to regularly submit their ideas. The

CPSO first publishes the changes through weekly Internet updates, which are available via a subscription to Classification Web (Library of Congress, Cataloging Distribution Service, n. d.). Later, these weekly updates are incorporated into print editions. For the purposes of this study, only the most recently printed edition was used.

DDC

Melvil Dewey created the first modern library classification in 1876. The first edition of his classification was comprised of only 12 pages of an introduction, 12 pages of tables, and an 18-page index. Dewey's classification possessed three attributes that greatly influenced other classification authors: (a) relative location, as opposed to fixed location; (b) high degree of specification; and (c) inclusion of a relative index (Rowley, 1987).

Relative location simply means that a library shelves media in relation to other media that a collection possesses (Taylor, 2004). With relative location, libraries may not assign books or other media to the same shelf or room. With fixed location, media has a stationary place in the shelving. Prior to the development of the DDC, books needed only a shelf mark to indicate their fixed position. Relative location led to the development of individual call numbers for books that are not connected to any fixed location (Foskett, 1982).

Later editions of the DDC continued to grow in length and in detail. Some persons criticized the first edition of the DDC for having too much detail, having nearly a thousand subject listings. Later editions sometimes face the opposite, a criticism for a lack of detail (Foskett, 1982). The most recent print edition, the 22nd, has a publishing date in 2003. The Online Computer Library Center (OCLC), based in Dublin, Ohio, publishes both print and online versions of the classification. The online version is titled WebDewey and is available on the OCLC Connexion website (OCLC, 2006). According to OCLC (n. d.), the DDC is the most widely used classification system in the world. Libraries in more than 135 countries use the DDC.

The DDC maintains a group of editors in the Decimal Classification Division of the Library of Congress. The editors assign classification numbers to new materials acquired by the Library of Congress and notice trends in the subjects of the materials (OCLC, n. d.). These trends influence future editions of the DDC. The editors forward suggestions for final approval to the Editorial Policy Committee of OCLC.

It should be noted that OCLC makes quarterly updates to DDC available through WebDewey, and that some libraries update their media and catalogs as WebDewey makes new information available. For the purposes of this study, only the most recent published edition, the 22nd edition (Mitchell, Beall, Martin, Matthews, & New, 2003), was used.

MSC

The American Mathematical Society (AMS) created the MSC in 1940 to classify articles in Mathematical Reviews, a publication of critical reviews and synopses of mathematical research. Since 1940, the AMS has completed several major revisions of the MSC to update the classification as new areas of mathematics have developed. There have also been changes in the basic notation style.

The MSC is prepared by a joint effort of the editorial staffs of Mathematical Reviews and Zentralblatt MATH. Mathematical Reviews continues to use the MSC to classify mathematical research. Since 1980, Mathematical Reviews has been available in an electronic database titled MathSciNet (American Mathematical Society, 2006), which also uses the MSC scheme. Zentralblatt Math is a similar print publication in Europe and is available electronically.

When a mathematics article author submits an article for publication to a journal or online database, the author selects one or more MSC numbers to self-classify the article. When specifying more than one number, an author labels one number as the primary number and the other numbers as secondary. These numbers are the basis by which Mathematical Reviews and Zentralblatt Math base their organization of their reviews. MathSciNet and the Zentralblatt Math electronic database are also searchable using the MSC notation.

The most recent revision of the MSC was in 2000, the first such revision in nine years. The entire classification is available online through the AMS website, as well as other places including the website for Zentralblatt Math. It is the 2000 version that the researcher used in this study.

CHAPTER 2

METHODS

The design of this study was influenced by Edmund Pajarillo's (2001) study that investigated the use of search databases by nurses. In the Pajarillo study, three nurses used and evaluated three health care-related search databases (Yahoo, Ask Jeeves, and MEDLINE), based on three criteria: utility, retrieval features, and user friendliness. The Pajarillo study included both a quantitative and a qualitative component. Pajarillo used a survey (scaled 1-10) to develop an understanding of the nurses' perceptions of the three databases based on their utility, retrieval features, and user friendliness. In addition, he used structured interviews to allow the three nurses to articulate their perceptions of the databases in regards to the three criteria.

This researcher applied Pajarillo's design to develop an understanding of the perceptions of eight mathematics professors in regards to three mathematics subject classifications. Like Pajarillo, the researcher used both a structured interview and a survey. For both the qualitative and quantitative methods, the researcher used three criteria (accuracy of the knowledge structure, level of detail, and ease of use of notation) throughout the data gathering and analysis.

Grounded Theory Study

Grounded theory was first proposed by Barney Glazer and Anhelm Strauss (1967) as one of the interpretive methods that share the common philosophy of phenomenology. Strauss and Corbin (1998, p. 12) describe grounded theory as "...theory that was derived from data, systematically gathered and analyzed through the research process." Grounded theory begins with a research question. The task of the researcher is to learn, through observation, conversation, and/or interviews, about various phenomena in relation to participants. By reviewing interview transcripts and field notes, the researcher identifies relationships in the data. Constant comparison is at the heart of grounded theory techniques. As the researcher compares the data, theory begins to emerge.

Grounded theory, as applied to this study, involved reading each interview transcript and identifying responses germane to the interview questions and overall research question for the study. In a critical data reduction process, the researcher identified categories or sequences of words within the responses. Coding is a process of simultaneously reducing the data by dividing it into units of analysis and coding each unit. After the categories are integrated and synthesized into a core set of categories, a narrative is developed that explains the properties and dimensions of the categories and the circumstances under which they are connected. This explanation of the phenomena under investigation is the theory developed based on the data. In this study, the researcher uses the term "theme" to describe such phenomena or categories and labels each theme with a unique number-letter combination.

Research in a University Setting

As with any research performed at a university, the researcher must gain approval from the Institutional Review Board (IRB) to begin the study. Part of this approval process is the completion of the Application for Approval to use Human Subjects. For this study, the IRB, part of the Office of Graduate Studies of Emporia State University, approved this application. This application is available in Appendix A. The IRB also requires that an Informed Consent document be signed by each participant. Appendix B contains the Informed Consent document.

Research Question

The following research question guided this study:

How useful do mathematics professors find the Dewey Decimal Classification, Library of Congress Classification, and American Mathematical Society Mathematics Subject Classification schemes when conducting research?

This research question is investigated in relation to three specific criteria: accuracy of the knowledge structure, appropriateness of the level of detail, and ease of use of the notation. The researcher explores the perceptions of mathematics professors about the three classification schemes employing these criteria to focus their interview and survey responses.

Definitions

Accuracy. "The quality of correctness as to fact and of precision as to detail in information resources and in the delivery of information services." (Reitz, 2006)

Caption. Name of the class, subclass, section, subsection, or division, such as "Mathematics" for the 510 division of DDC.

Class. In LCC, any of the largest divisions of the classification, denoted by a single letter. For example, "Q Science" is a class.

Classification schedule. "A listing of the hierarchy of a classification scheme along with the notation for each level." (Taylor, 2004, p. 359)

Classification. "The placing of objects into categories; in organization of information, classification is the process of determining where an information package fits into a given hierarchy and often then assigning the notation associated with the appropriate level of the hierarchy to the information package…" (Taylor, 2004, p. 359)

Division. For DDC, any of the 100 portions of the schedule that are the next level of classification after the 10 main classes. For example, "510 Mathematics" is a division.

Hierarchy. "An arrangement by which categories are grouped in such a way that a concept (e.g., class or discipline) is subdivided into subconcepts of an equal level of specificity, each of those subconcepts are further subdivided into subcategories, and so on…." (Taylor, 2004, p. 356)

Main class. For DDC, any of the 10 portions of the schedule that are the broadest level of classification. For example, "500 Natural sciences and mathematics" is a main class.

Notation. "A representation in a system, such as a classification system, with a set of marks, usually consisting of letters, numbers, and/or symbols." (Taylor, 2004, p. 372)

Primary classification. For MSC, one of the author-identified classification numbers of an article or monograph. Many mathematics journals require the author to provide one classification number that best describes the subject of the article.

Secondary classification. For MSC, one of the author-identified classification numbers of an article or monograph. Many mathematics journals allow authors to provide more than one classification number. Any additional numbers besides the primary number are considered secondary classification numbers.

Section (DDC). Any of the 1000 portions of the schedule that are the next level of classification after the 100 divisions. For example, "515 Analysis" is a section.

Section (MSC). Any of the largest divisions of the classification, denoted by a two-digit number. For example, "11 Number Theory" is a section. This is also referred to as the two-digit level of this classification.

Semantics. "The meaning of a string of characters, as opposed to the syntax, which dictates the structure, independent of meaning." (Taylor, 2004, p. 377)

Specificity. "The level of subject analysis that is addressed by a particular controlled vocabulary...." (Taylor, 2004, p. 378)

Structure. "Arrangement in a definite pattern of the parts of a whole." (Taylor, 2004, p. 378)

Subclass. In LCC, any of the divisions of the classification that is the next level after class. A subclass is denoted by more than one letter. For example, "QA Mathematics" is a subclass.

Subject. "Any one of the topics or themes of a work, stated explicitly in the text or title or implicit in its message. In library cataloging, a book or other item is assigned one or more subject headings as access points, to assist users in locating its content by subject." (Reitz, 2006)

Subsection. For MSC, the next level of classification after section, denoted by a letter following the two-digit number for the section. For example, "11B Sequences and sets" is a subsection. This is also referred to as the three-digit level of this classification.

Limitations

This study investigates the use and evaluation of three mathematics subject classifications by mathematics professors. It should be noted that the participant sample size is small and limited to a few Midwestern university mathematics departments. It may not reflect the views of other mathematics professors. Due to time constraints, no female participants were included in this study. The study is limited by the type of the universities selected, as all three institutions are public universities; no private universities were selected.

Participant Selection

Before the selection of participants, the researcher developed basic criteria for the number and scope of the participant pool. These criteria included having a pool that would generally reflect the views of a wider population, while being small enough to interview all participants in the timeframe for completion of the research. With these criteria in mind, the researcher selected four universities as a possible domain for participant selection. These four universities are all Midwestern, public universities, located in Kansas and Missouri. At each of the four universities, five participants would be interviewed and surveyed, for a total of 20 participants.

Participants in this study were selected with the assistance of a mathematics professor who is actively involved and well acquainted with regional university mathematics departments. This person identified a mathematics professor, the "contact person," for each of four universities (labeled A, B, C, and D in this study). Each of these contact persons was either a professor at the respective university or had a high degree of contact with the mathematics faculty at the university. Each contact person was asked to suggest participants within his department based on mathematical expertise, interest by the participants, and the researcher's access to the participants. Some contact persons also used personal familiarity as a criterion.

At university A, the contact person immediately suggested a different professor to act as a contact person but offered himself as a participant. The researcher then contacted the alternate contact person who offered himself as a participant and suggested names of three other persons as participants. The researcher contacted these three potential participants. Two of the three responded favorably to the interview/survey request. One potential participant did not respond to the request. The researcher conducted interviews and surveys with the four professors who did respond.

At university B, the contact person identified the names of only four potential participants. Due to time constraints, the researcher contacted two potential participants. One potential participant refused the interview, while the other accepted. The researcher conducted the interview and survey with the participant. The participant at university B also acted as the contact person for university C.

At university C, the contact person provided over a dozen possible participant names but identified three potential participants that best met the criteria. The researcher contacted the three professors and conducted the interviews and surveys. Due to time constraints, the researcher contacted no other professors at university C.

At university D the contact person identified one potential participant. This identification took place after the other interviews and surveys had been completed and after the data analysis had begun. Because of time constraints, the researcher decided not to contact the potential participant.

Overview of Participating Universities

The three universities participating in this research are public universities located in Kansas and Missouri. The universities range in size from approximately 6,000 students to 29,000 students. Each university offers at least one PhD degree program and has a wide variety of baccalaureate and masters degree programs. All three universities offer baccalaureate and masters degrees in mathematics, while universities A and C offer doctoral programs in mathematics.

University A, from which the researcher interviewed and surveyed four participants, has an enrollment of approximately 23,000 students. This university has approximately 800 faculty members, of which 28 are mathematics faculty members at a rank of assistant professor or above. The mathematics department has approximately 80 graduate students. This university is in a city of 45,000 persons.

University B, from which the researcher interviewed and surveyed one participant, was the smallest of the three universities, enrolling approximately 6,000 students. University A has approximately 300 faculty members, including nine mathematics faculty members at an assistant professor rank or above. The mathematics department has approximately 15 graduate students. This university is in a city of 30,000 persons.

University C, from which the researcher interviewed and surveyed three participants, has an enrollment of approximately 29,000 students. University C has approximately 1,150 faculty members, of which 42 are mathematics faculty members at a rank of assistant professor or above. The mathematics department has approximately 125 graduate students. This university is in a city of 90,000 persons.

Overview of Participants

Each participant, eight in number, is a mathematics professor, currently teaching at one of three universities. Each participant is male. All participants actively pursue one or more research interests in the area of mathematics. All participants have PhD degrees, from which seven degrees are from universities in the United States. One participant received his degree from a university in Ukraine during the time that Ukraine was part of the Soviet Union.

The participants have had their respective doctoral degrees an average of 19 years. The participant with the most recently awarded degree received his PhD in 2001, while the participant with the earliest degree graduated in 1968. Seven of the participants hold the rank of full professor, while one participant holds the rank of assistant professor.

Synopsis of Individual Participants

For the purposes of this study, the researcher will refer to each participant by a unique number, assigned in the order by which the researcher conducted the interviews. What follows is a brief synopsis of each participant, including: a) professorial rank, b) year the participant received his PhD degree, c) United States Census-defined regional division of the university at which the participant received his degree (U. S. Census Bureau, 2001), and d) area(s) of research interest.

Participant 1 holds the rank of professor at university A. Participant 1 received his PhD in 1984 from a major public university in the East North Central United States. For this study, the researcher has identified number theory as the main research area of participant 1.

Participant 2 holds the rank of professor at university A. Participant 2 received his PhD in 1989 from a major public university in the New England regional division of the United States. For this study, the researcher has identified group theory as this participant's main research area.

Participant 3 holds the rank of professor at university A. Participant 3 received his PhD in 1968 from a private university in the New England regional division of the United

States. For this study, the researcher has identified functions of complex variables as participant 2's main research area.

Participant 4 holds the rank of assistant professor at university B. Participant 4 received his PhD in 2001 from a large public university in the West North Central United States. For this study, the researcher has identified numerical analysis and Fourier analysis as main interests of this participant.

Participant 5 holds the rank of professor at university A. Participant 5 received his PhD in 1985 from a private university in the Middle-Atlantic regional division of the United States. For this study, the researcher has identified mathematics education as participant 5's primary research interest.

Participant 6 holds the rank of professor at university C. Participant 6 received his PhD in 1982 from a public university in Ukraine. At the time the participant received his degree, Ukraine was part of the Soviet Union. For this study, the researcher has identified dynamical systems and functional analysis as this participant's primary research interests.

Participant 7 holds the rank of professor at university C. Participant 7 received his PhD in 1993 from a large public university in the Pacific regional division of the United States. For this study, the researcher has identified convex geometry and partial differential equations as areas of interest for this participant.

Participant 8 holds the rank of professor at university C. Participant 8 received his PhD in 1994 from a large public university in the South Atlantic United States. For this study, the researcher has identified harmonic analysis and partial differential equations as main research interests of this participant.

Identifying Each Participant's Research Area

The researcher initially contacted each participant using email or phone and set up an interview time for each participant. The researcher also asked each participant to identify an area of mathematical expertise in which the participant was currently conducting research or at least had conducted research recently.

For each participant, the researcher also gathered personal information about research interests using curriculum vitae and from biographical information on mathematics departmental websites. This data included a basic subject analysis of recent publications by the participants. Table 1 contains a summary of participant research interests.

Making Classification Excerpts

In order to make classification excerpts for review by each participant, the researcher first reviewed the classification schedules of all three classifications investigated in this research. Then, after identifying the research areas of the participants, the researcher identified excerpts of the three classifications that matched those research interests. In some instances, research areas were too narrow in scope to provide an adequate context for evaluating structure accuracy or level of detail. In these instances, the researcher identified excerpts in the classifications that were broader, but encompassed the interests. Appendices C-E are example excerpts of each of the three classifications.

For each participant, the researcher selected between one and three excerpts for each of the three classifications. The researcher typed and printed the excerpts in preparation for each participant interview. For each excerpt, the researcher removed

Table 1

Participants' Mathematics Expertise Areas

Participant No.	Area(s) of expertise
1	Number theory
2	Group theory
3	Functions of complex variables
4	Numerical analysis, Fourier analysis
5	Mathematics education
6	Dynamical systems, functional analysis
7	Convex geometry, partial differential equations
8	Harmonic analysis, partial differential equations

references such as "See" and "See also." The researcher retained all statements beginning "including," which are often included in the DDC. Statements such as "class here" in DDC were modified to read "including." All bracketed notation, signifying notation in a previous edition in DDC, were removed. Indenting in DDC and LCC were maintained. Bold headings in MSC were maintained.

For each excerpt, the researcher removed the name of the classification and used a colored marker to mark each excerpt. The participants were not told the name of the classifications, unless the participant explicitly asked for such information during the interview. All LCC excerpts were marked at the top in red; DDC excerpts, green; and MSC, blue. The researcher marked the survey questions about each classification with corresponding colors.

Interviews

After preparing the classification excerpts for a participant, the researcher conducted the face-to-face interview with the participant. For each of the eight participant interviews, the researcher visited the faculty office of the participant. Also for each interview, the researcher audio recorded the entire interview on micro-cassette. In addition, the researcher presented the informed consent document to each participant. Each participant signed and dated the informed consent document. The researcher then handed copies of the classification excerpts to the participant all at once. The researcher pointed out to the participant that the red, green, and blue colors indicated different classification schemes to ensure the participants' understanding of the excerpts. As stated previously, the classification excerpts did not display the names of the classifications.

The researcher began the interview by presenting an overview of the research study. Then, the researcher asked the interview questions (Appendix F), nine in number, with three concerning each of the three classifications: LCC, DDC, and MSC. For each participant, the researcher asked all three questions concerning LCC first before moving to DDC, and finally MSC.

For each of the three classifications, the three questions concern 1) accuracy of the knowledge structure, 2) appropriateness of the level of detail, and 3) how easy the notation is to use. At the conclusion of the interview, the researcher informed the participant that there would be an opportunity to review the transcript of the interview and correct any statements. Many participants continued to offer comments after the final question of the interview, but the researcher did not include those responses.

Transcription and Member Check

Using data from interviews and surveys, the researcher created a rich picture of the participants' perceptions of usefulness of the three classification schemes. The researcher performed an analysis of both the qualitative and quantitative data sets and then combined the analyses to form the final conclusions.

For the qualitative data, the researcher began by transcribing all of the eight interviews, a total of approximately five hours of interview time. After the researcher completed the transcriptions, the researcher contacted each of the participants by postal mail and sent the respective transcription to each mathematics professor for a participant member check. The researcher instructed the participants to make corrections to the transcriptions if necessary and then return any corrections via postal mail, phone, or email. For some participants, the researcher identified specific locations in the transcript that were unclear by using a boldface type. Participants receiving such transcriptions received a slightly different cover letter describing the meaning of bolded words and phrases. (For the two cover letters, see Appendices H and I.) The researcher presented a deadline of approximately two weeks to return the transcript and instructed the participant that if there was no reply that the researcher would assume that no corrections were necessary. Only two participants replied to the member check. One had no corrections. The other had a variety of corrections to grammar and, in some parts, meaning. The researcher incorporated corrections to the meaning of the interviewee's responses when analyzing the data.

Interview Data Analysis

Towards analyzing the interview data, the researcher performed the following steps:

1. The researcher separated each transcript by interview question. The researcher asked nine questions, yielding nine transcript portions for each transcript.
2. The researcher collected all interview transcript portions and arranged them by question. For example, all portions relating to Question 1 were grouped together.
3. The researcher marked response items to the questions. A "response item" is a phrase, a sentence, or a group of sentences that directly answer an interview question. Within each participant's answer to a question, there exist multiple response items. This step eliminates all unrelated "talk."
4. The researcher organized all response items into a spreadsheet.
5. The researcher identified themes among the response items to each question and assigned the themes unique identification numbers.

6. The researcher coded each response item, relating the item to a particular theme.
7. The researcher counted the response items in relation to each theme, as well as counting the total number of responses to each question. The researcher also calculated the percentage of responses related to each theme as compared to the total responses for each question.

This data analysis is inspired by the grounded theory method of comparative analysis (Strauss and Corbin, 1998) in order to interpret the data and to discover theory relevant to the research questions that are generalizable, relevant, valid (fit), and modifiable for mathematicians, librarians, and classification designers.

Surveys

After the interview, the researcher handed the survey to the participant. The survey (Appendix G) contained nine statements that correspond to the nine interview questions in content. The survey statements each have a Likert scale, by which the participant circled a response marked "Strongly disagree," "Disagree," "No opinion," "Agree," or "Strongly agree." The five possible responses also are paired with a numeric value, from 1 for "Strongly disagree" to 5 for "Strongly agree." After the survey, the researcher thanked the participant for his time.

For each survey topic, the researcher collected all survey responses and organized them into a spreadsheet. Then, for each of the nine topics, the researcher calculated the arithmetic means and standard deviations of the survey responses.

CHAPTER 3

RESULTS

For each of the nine interview questions (three for each classification, relating to each of three criteria), the researcher identified three or more themes in the response items to the questions. The researcher also recognized that some response items fell outside these themes and created a category labeled "Other" for these response items. After coding the response items according to the identified themes, the researcher counted the response items that related to each theme and translated those counts as a percentage of total response items to each question. The results are organized in the same order as the interview, beginning with all results concerning LCC, then DDC, and finally MSC. Within each classification, the results are organized by the three criteria. The three criteria are simply abbreviated as "Structure," "Detail," and "Notation."

The survey contained nine statements, each corresponding to an interview question. For each of the statements, the participant circled one of five responses, ranging from 1—"Strongly disagree" to 5—"Strongly agree." The data gathered from the survey is contained in Table 2.

LCC

Question 1: Structure

The eight participants offered a total of 82 response items to the interview question concerning the accuracy of structure of the LCC. The researcher identified four themes from these response items: participants possess uncertainty about the classification scheme (Theme 1a); participants question the accuracy of the classification structure (1b); participants believe that mathematics is a complex field of study (1c);

Table 2

Participant Survey Responses

Likert value	1	2	3	4	5
Question No.	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
		LCC			
1: Structure	0	1	3	4	0
2: Detail	0	6	1	1	0
3: Notation	0	1	3	2	2
		DDC			
4: Structure	2	1	1	4	0
5: Detail	2	3	0	3	0
6: Notation	0	1	4	3	0
		MSC			
7: Structure	0	0	0	2	6
8: Detail	0	1	0	0	7
9: Notation	0	0	0	3	5

Note: The values in the table represent the quantity of participants who circled the response.

and participants accept the classification structure (1d). Table 3 contains data concerning the quantities and percentages of response items and contains example response items from participants.

Among the themes to question 1, participants most often offered response items that referred to theme 1b, that the participants question the accuracy of the classification structure. Note that over half (58.5%) of response items to question 1 referred to this theme. Participant 5, noting that topics are not grouped in ways he would prefer, stated, "These things end up funny other places." Participants questioned the structure for several reasons, including that the LCC has not remained current with changes in the structure of the field. Another reason given is that the participants feel that there is a lack of cooperation and communication between experts in mathematics and the persons who design the LCC. Participant 3 explicitly said, "They [LCC designers] refuse to cooperate with the American Mathematical Society, who has offered to place a standing committee at their disposal." Table 3 contains data about the response items and themes and gives example response items for each theme in relation to question 1.

The two most common themes differ from the survey responses, in that only one participant indicated a disagreement that the excerpts from the LCC accurately reflect the knowledge structure of the field of study. The researcher suggests that the interview results are a better indicator of the participants' perceptions, due to the high percentage of interview response items in agreement with each other (such as for theme 1b).

Table 3

Themes of Participants' Interview Responses, Question 1: LCC—Structure

No.	R. Items	Perc.	Theme	Example Response Item
1a	10	12.2%	Participants possess uncertainty about the classification scheme.	I wasn't aware you could put them in special categories like that.
1b	48	58.5%	Participants question the accuracy of the classification structure.	These things end up funny other places.
1c	14	17.1%	Participants believe that mathematics is a complex field of study.	I don't know if there's a best way.
1d	10	12.2%	Participants accept the classification structure.	It looks good. I don't see any mistakes.
	82	100.0%	Total	

Question 2: Detail

The participants offered a total of 76 response items to the interview question concerning the level of detail of the LCC. The researcher identified four themes in the response items: participants believe that the classification needs a higher degree of detail (2a); participants believe that the classification is missing key mathematics topics (2b); participants believe that the classification is inconsistent in the inclusion or degree of prominence it gives specific mathematics topics (2c); and participants accept the level of detail (2d). Table 4 contains data about the response items and themes and gives example response items for each theme in relation to question 2.

Among the response items for question 2, participants referred to theme 2a the most, that the LCC needs a higher degree of detail. Participant 7, when referring to an excerpt of the LCC concerning the mathematical field of partial differential equations, stated, "I would have expected this to be further subdivided into at least three or four sub-areas to make it easy to find something."

The second most cited theme by the participants was theme 2b, that the LCC is missing key mathematics topics. The participants mentioned many topics, including elliptic curves, pseudo-differential operators, and, in the area of mathematics education, topics concerning teaching methods in specific fields of mathematics. Because the participants each only see one to three excerpts of the classification, it is possible that some of the many topics mentioned are included in other portions of the classification. In that case, the criticism would be aligned with question 1, concerning the structure of the classification. The responses to the survey for question 2 are in line with the interview

Table 4

Themes of Participants' Interview Responses, Question 2: LCC—Detail

No.	R. Items	Perc.	Theme	Example Response Item
2a	24	31.6%	Participants believe that the classification needs a higher degree of detail.	I would have expected this to be further subdivided into at least three or four sub-areas to make it easy to find something.
2b	22	28.9%	Participants believe that the classification is missing key mathematics topics.	Where is the analytic number theory?
2c	20	26.3%	Participants believe that the classification is inconsistent in the inclusion or degree of prominence it gives specific mathematics topics.	There's certain topics that seem to have a lot of detail, and others that don't seem to have much at all.
2d	5	6.6%	Participants accept the level of detail.	This is detailed and that is very nice.
2e	5	6.6%	Other	Should Congress follow AMS or AMS follow Congress?
	76	100.0%	Total	

response themes. Six of eight participants responded “Disagree” to the survey statement, “This classification uses an appropriate level of detail.” Only one participant responded “Agree” to the statement. This corresponds to theme 2d, concerning acceptance of the level of detail. Only 6.6% of interview response items for question 2 referred to acceptance of the level of detail.

Question 3: Notation

The participants offered a total of 38 responses to the interview question concerning the notation for the LCC. The researcher identified four themes in the response items: participants believe that the construction of the notation is beneficial (3a); participants feel that notation is irrelevant to a classification system’s effectiveness (3b); participants believe that familiarity with a notation system influences the degree that the participant accepts the notation (3c); and participants accept the notation (3d). Table 5 contains data about the response items and themes and gives example response items for each theme in relation to question 3.

Among the themes relating to LCC notation, participants most frequently alluded to theme 3c, that familiarity with a notation system influences the degree that the participant accepts the notation. While this theme is not necessarily criticism or praise of the notation, it does shed light on the other commonly cited themes for this question.

Two other themes tied for the second-most cited theme. One of the two themes is 3a, that participants believe that the construction of the notation is a benefit. Participants specifically mentioned the use of a combination of letters and numbers, as opposed to all

Table 5

Themes of Participants' Interview Responses, Question 3: LCC—Notation

No.	R. Items	Perc.	Theme	Example Response Item
3a	7	18.4%	Participants believe that the construction of the notation is beneficial.	Has the advantage over Dewey Decimal that…it can be a lot more fine grained.
3b	5	13.2%	Participants feel that notation is irrelevant to a classification system's effectiveness.	It doesn't really matter.
3c	13	34.2%	Participants believe that familiarity with a notation system influences the degree that the participant accepts the notation.	I was never a big fan of this notation, but you get used to it.
3d	7	18.4%	Participants accept the notation.	As long as it is consistent, I'm happy with it, and it is consistent.
3e	6	15.8%	Other	I'm kind of neutral on the numbers because I don't know that I would use it to my advantage.
	38	100.0%	Total	

numbers in for the DDC. Participants also recognized that by using the 26 letters of the alphabet instead of the ten numbers, one could subdivide a topic into more subcategories. Participant 8 referred to the ability to memorize notation, that a combination of letters and numbers makes this easier.

The other theme tied for the second-most cited is theme 3c, that participants accept the notation. Participants mentioned theme 3c in conjunction with themes 3a and 3b. They recognize part of the reason that they accept it is because of their experience and familiarity with it and that the construction of the notation is a factor towards acceptance.

Note that this generally positive attitude towards acceptance of the notation for the LCC corresponds well to the survey responses for this topic. Only one participant marked "Disagree" to the statement, "For this classification, the notation is easy to use." Two participants responded "Strongly agree" to the statement, while two more responded "Agree."

DDC

Question 4: Structure

The participants offered at total of 48 response items to the interview question about the accuracy of the structure of the DDC. The researcher identified four themes in the responses to this question: participants question the accuracy of the classification structure (4a); participants possess uncertainty about the classification scheme (4b); participants believe that mathematics is a complex field of study (4c); and participants accept the classification structure (4d). Table 6 contains data about the response items and themes and gives example response items for each theme in relation to question 4.

Table 6

Themes of Participants' Interview Responses, Question 4: DDC—Structure

No.	R. Items	Perc.	Theme	Example Response Item
4a	34	70.8%	Participants question the accuracy of the classification structure.	I don't understand why functional equations belong to functional analysis.
4b	4	8.3%	Participants possess uncertainty about the classification scheme.	One-dimensional configurations, including angles…I have difficulty measuring what books this would correspond to.
4c	7	14.6%	Participants believe that mathematics is a complex field of study.	It's going to be hard for anybody to simply create and classify that one [groups and rings].
4d	3	6.3%	Participants accept the classification structure.	This has all the types of words I was hoping to see over here [in LCC].
	48	100.0%	Total	

When analyzing the responses to the interview question concerning the accuracy of the structure of the DDC, it is immediately apparent that the participants question the accuracy. Over two-thirds (70.8%) of the response items to question 4 questioned the structure's accuracy (theme 4a). Participant 6 stated, "I don't understand why functional equations belong to functional analysis." Participant 7 said, "There's no clear pattern as to how the subjects are oriented or listed." Other participants give similar kinds of examples. No other theme had a high of percentage of response items by participants.

The survey statement for this topic was the same as for question 1, except that it concerned the excerpts dealing with the DDC. The survey statement elicited a variety of different responses. Four participants responded "Agree." One marked "No opinion." One responded "Disagree," while two responded "Strongly disagree." There is a dichotomy of responses in the survey results that is not present in the interview responses. The researcher again suggests that the interview results are a better indicator of the participants' perceptions, due to the high percentage of interview response items in agreement with each other.

Question 5: Detail

The participants offered 62 response items to the interview question concerning the level of detail of the DDC. The researcher identified four themes in the response items to this question: participants believe the classification needs a higher degree of detail (5a); participants believe that the classification is missing key mathematics topics (5b); participants accept the level of detail (5c); and participants possess uncertainty about the level of detail (5d). Table 7 contains data about the response items and themes and gives example response items for each theme in relation to question 5.

Table 7

Themes of Participants' Interview Responses, Question 5: DDC—Detail

No.	R. Items	Perc.	Theme	Example Response Item
5a	31	50.0%	Participants believe the classification needs a higher degree of detail.	There is no detail. It is vague description. For example, under partial differential equations, you could have a thousand different topics.
5b	12	19.4%	Participants believe that the classification is missing key mathematics topics.	So many things are missing here.
5c	11	17.7%	Participants accept the level of detail.	Very good in the headings right here [elementary number theory, analytic number theory, and algebraic number theory].
5d	6	9.7%	Participants possess uncertainty about the level of detail.	I hope that the fact that they're [differential forms] here doesn't mean that you cannot find them in any other place.
5e	2	3.2%	Other	It's going to be really hard to find a book [using DDC in an academic library].
	62	100.0%	Total	

Among the themes for question 5, responses clearly pointed to theme 5a, that participants believe the classification needs a higher degree of detail. Exactly 50% of response items referred to this theme, which exceeds the response item percentage for the similar theme 2a for LCC. Quotes relating to this theme include the simple statement by Participant 3, "I would say it's inadequate." Participant 7 stated, "There is no detail. It is vague description. For example, under partial differential equations, you could have a thousand different topics."

Participants also offered many response items that relate to theme 5b, that DDC is missing key topics. Among areas that participants suggested for inclusion are finite properties of functions and sequences of integers. Like with the LCC, participants only saw a few excerpts of DDC and might not have been aware that other portions of the classification may contain some of the topics perceived as missing.

A third theme for question five is that some participants accepted the level of detail (theme 5c). Participants were especially willing to make such comments when a specific topic had a higher level of detail than the corresponding topic in the LCC. Participants made comments such as the one by Participant 8 who liked the fact that DDC structured partial differential equations into its three major subcategories. The LCC did not divide partial differential equations into these same subcategories.

The survey statement for this topic was the same as for question 2, except that it concerned the excerpts dealing with the DDC. The participant pool offered the following responses: "Strongly disagree," "Disagree," and "Agree." Note that five of the responses either "Disagree" or "Strongly disagree" with the survey statement, "This classification uses an appropriate level of detail." This survey statement is only one of two survey statements with this degree of disagreement (The survey statement for question 2 is the other).

Question 6: Notation

The participants offered 21 response items to the interview question relation to the notation of DDC. The researcher identified four themes in the participants' response items: participants believe that the construction of the notation hinders its effectiveness (6a); participants believe that familiarity with a notation system influences the degree that a person will accept the notation (6b); participants feel that notation is irrelevant to a classification system's effectiveness (6c); and participants accept the notation (6d). Table 8 contains data about the response items and themes and gives example response items for each theme in relation to question 6.

Within the response items for question 6, the participant responses most often (42.9%) referred to theme 6a, that the construction of the DDC notation hinders its effectiveness. Participants mentioned repeatedly that they prefer a combination of letters and numbers instead of only numbers. Participants also cited that, using numbers, a concept can only be separated into ten categories, instead of 26, using letters.

A significant but smaller percentage (28.6%) of participant response items referred to their acceptance of the notation (theme 6d). Participant 7 stated, "It's…more straightforward," and "The notation…would be easier to use than the QA business."

The survey statement for this topic was the same as for question 3, except that it concerned the excerpts dealing with the DDC. The survey results display that half of the participants had no opinion about the ease of use of the DDC notation. Theme 6c falls in line with the survey in that regard, that participants feel that notation is irrelevant to the effectiveness of a classification.

Table 8

Themes of Participants' Interview Responses, Question 6: DDC—Notation

No.	R. Items	Perc.	Theme	Example Response Item
6a	9	42.9%	Participants believe that the construction of the notation hinders its effectiveness.	If you have more than ten [subcategories], more than nine, it's going to be hard [to subcategorize].
6b	3	14.3%	Participants believe that familiarity with a notation system influences the degree that a person will accept the notation.	You can get used to it.
6c	3	14.3%	Participants feel that notation is irrelevant to a classification system's effectiveness.	It is not important.
6d	6	28.6%	Participants accept the notation.	It's…more straightforward.
	21	100.0%	Total	

Mathematics Subject Classification

Question 7: Structure

The participants offered a total of 71 response items to the question concerning the accuracy of the structure of the MSC. The researcher identified four themes in the participants' response items: participants recognize the AMS classification as being the authoritative classification in mathematics (7a); participants accept the classification structure (7b); participants feel that the AMS classification is better than the LCC or DDC (7c); and participants question the accuracy of the structure (7d). Table 9 contains data about the response items and themes and gives example response items for each theme in relation to question 7.

The themes relating to the accuracy of the structure were very positive. Of the themes for this question, participants referred to their acceptance of the structure (theme 7b) the most. Participant 3 stated, "It's the gold standard. Can't be improved upon." Participant 5 said, "It's a very easy system to use," and "It's subdivided the way I see things subdivided." Similar to theme 7b is theme 7c, that participants feel that the MSC structure is better than LCC or DDC. Several response items mentioned the idea that LCC or DDC would benefit by using the MSC as a guide for the basis of their classifications. Several responses also alluded to theme 7a, that the MSC is the authoritative classification in mathematics. Participant 6 stated, "My impression of how mathematics should be structured...was formed by this document," and continues, "So many people have been affected by this and accepted it." Participant 3 simply states, "This is the worldwide schema of classification." Note that themes 7a, 7b, and 7c all are

Table 9

Themes of Participants' Interview Responses, Question 7: Mathematics Subject Classification—Structure

No.	R. Items	Perc.	Theme	Example Response Item
7a	13	18.3%	Participants recognize the AMS classification as being the authoritative classification in mathematics.	So many people have been affected by this and accepted it.
7b	22	31.0%	Participants accept the classification structure.	It's the gold standard. Can't be improved upon.
7c	11	15.5%	Participants feel that the AMS classification is better than the LCC or DDC.	It would be nice if they went through and just took all of these bold words and made sure that those were some of the main headings in [LCC and DDC].
7d	13	18.3%	Participants question the accuracy of the structure.	There's no such a heading as "Harmonic analysis."
7e	12	16.9%	Other	Can't say if this is accurate or not.
	71	100.0%	Total	

complimentary themes in mathematics, yielding a combined total of 64.8% of response items to this question.

Some response items (18.3%), however, disagreed with generally positive attitude that participants had towards the MSC structure. Theme 7d characterizes the response items that question the accuracy of the structure. Participant 8 recognized the lack of a specific MSC section on harmonic analysis. While topics in harmonic analysis appear in the MSC, they are not grouped together under a single heading entitled as such.

The survey statement for this topic was the same as for questions 1 and 4, except that it concerned the excerpts dealing with the MSC. The survey responses to the corresponding topic were overwhelmingly positive. The participants all responded "Agree" or "Strongly agree" to the statement, "This classification accurately reflects the knowledge structure of this field of study," with six participants answering "Strongly agree." This was only one of two survey statements in which all participants marked only the "Agree" and "Strongly agree" responses.

Question 8: Detail

The participants provided a total of 39 response items to the interview question about the level of detail of the MSC. The researcher identified three themes in the response items: participants question the level of detail (8a); participants accept the level of detail (8b); and participants feel that the flexibility of the classification is a significant contributor to its effectiveness (8c). Table 10 contains data about the response items and themes and gives example response items for each theme in relation to question 8.

Concerning the level of detail of the MSC, the participants' interview response items were very positive. Over three-quarters of responses (76.9%) referred to an

Table 10

Themes of Participants' Interview Responses, Question 8: Mathematics Subject Classification—Detail

No.	R. Items	Perc.	Theme	Example Response Item
8a	4	10.3%	Participants question the level of detail.	To me, this is not detailed enough.
8b	30	76.9%	Participants accept the level of detail.	It's certainly nice to have it more focused.
8c	3	7.7%	Participants feel that the flexibility of the classification is a significant contributor to its effectiveness.	As that [quasi-conformal mapping] begins to become an important subdivision, it will get its own [line in the classification].
8d	2	5.1%	Other	As far as organizing books goes, this sort of a category would create an allergic reaction even more than MathSciNet, which is designed from a practical standpoint.
	39	100.0%	Total	

acceptance of the level of detail. Participant 4 simply stated, "This is a lot more detailed," when comparing the MSC to LCC or DDC, and goes on to say "It's certainly nice to have it more focused." Participant 6 said, "This is a better classification...has some more categories which are not in [LCC or DDC]."

The survey statement for this topic was the same as for questions 2 and 5, except that it concerned the excerpts dealing with the MSC. The survey responses to this question follow in step with the interview responses. Seven of eight participants responded "Strongly agree" to the statement, "This classification uses an appropriate level of detail." No other survey statement received as many "Strongly agree" responses. Based on the interview and survey responses, it can be inferred that the participants find that the level of detail is the strongest attribute of the Mathematics Subject Classification.

Question 9: Notation

The participants provided 29 response items to the question concerning the notation of the MSC scheme. The researcher identified four themes among the provided response items: participants like the construction of the notation (9a); participants identify the flexibility of notation as an important indicator of overall effectiveness of the classification scheme (9b); participants find the notation to be the authoritative notation in mathematics (9c); and participants accept the notation (9d). Table 11 contains data about the response items and themes and gives example response items for each theme in relation to question 9.

Two themes for the MSC notation tied for the most number of response items. One of these two is theme 9b, that participants recognize that the flexibility of the notation to be able to add new areas of mathematics is an important indicator of the

Table 11

Themes of Participants' Interview Response Items, Question 9: Mathematics Subject Classification—Notation

No.	R. Items	Perc.	Theme	Example Response Item
9a	5	17.2%	Participants like the construction of the notation.	The letter gives you a little bit of breakup.
9b	9	31.0%	Participants identify the flexibility of notation as an important indicator of overall effectiveness of the classification scheme.	…maximal spaces for the future insertion.
9c	4	13.8%	Participants find the notation to be the authoritative notation in mathematics.	I think most mathematicians… [are] thinking in terms of Math Review classifications.
9d	9	31.0%	Participants accept the notation.	If that person [an article author] includes subject classification numbers, then you have a much better idea [of the article's subject].
9e	2	6.9%	Other	I can recite, maybe, 20-25 numbers… that have to do with areas that I'm working in.
	29	100.0%	Total	

overall effectiveness of the scheme. Several participants mentioned specifically that the MSC is smart to leave room between classification numbers for future insertion. Other participants alluded to the idea that the American Mathematical Society spots trends in mathematics publishing and factors these trends in making the MSC.

The other of these two themes is that the participants accept the notation (theme 9d). Participant 8 stated, "It…helps me recognize other papers," and continues, "if that person includes subject classification numbers, then you have a much better idea [of the article's subject]." Related to this general theme is also theme 9a, that participants like the construction of the notation. Participants mentioned that they like that a letter breaks up the notation, instead of a string of numbers as in the DDC. Like for question 7, many of the themes are similar in their positive perceptions of the MSC. The sum of percentages for themes 9a-9d is an overwhelming 93.0%. The remainder of response items (2 responses for a total of 6.9%) were more neutral in nature.

The survey statement for this topic was the same as for questions 3 and 6, except that it concerned the excerpts dealing with the MSC. The survey responses for this topic were similar in nature to the other survey topics for the MSC, with overwhelming agreement to the survey statement. The survey statement was, "For this classification, the notation is easy to use." All eight participants marked either "Agree" or "Strongly agree," with five participants marking "Strongly agree."

Summary of Interview Response Items

The eight participants offered a total of 470 response items over a total of approximately five hours of interviews. The researcher identified 35 themes (including duplicates) present in the responses. Broken down by classification, 196 response items concerned the LCC, 154 response items concerned DDC, and 136 response items concerned MSC. Four response items did not specifically concern the nine questions (these are grouped together as theme 10a).

Summary of Survey Responses

Each of the eight participants responded to each of the nine survey questions, yielding a total of 72 responses. Twenty-four responses refer to each of the classifications.

CHAPTER 4

DISCUSSION

Linking to the Research Question

The ultimate perception here is that mathematics professors find the MSC very useful. While there exists some caution among mathematics professors about how the MSC will adapt to future changes in mathematics, the overall feeling is that the MSC represents the field of mathematics well and presents a level of detail that meets the needs of mathematics experts when conducting research.

Mathematics professors find the LCC and DDC to be much more lacking in both the accuracy of the structure of the classifications, as well as the in the level of detail, when compared to the Mathematics Subject Classification. The deficiencies in the accuracy of the structure and the level of detail lead to decreased usability when conducting research. Between DDC and LCC, the DDC suffered the most critical reviews by the participants for both its structure and detail.

LCC

Reviewing the themes relating to the LCC, participants do not find LCC to be a very useful classification scheme. Participants were somewhat critical of LCC's structure, while they were very critical about the level of detail. The participants were, however, complimentary of the notation.

Consider the LCC and its purpose. The LCC began as a way to classify books and other items at the Library of Congress—a central purpose still today. As stated in the literature review, the Library of Congress bases changes on trends in the subject matter of materials received by the library. Other libraries can also suggest modifications to the

Library of Congress. To the researcher, this appears to be a reactive, not proactive approach. By incorporating more collaboration with experts in mathematics, the Library of Congress can take a more proactive approach, allowing the LCC scheme to be very current, anticipating the needs of the mathematics community.

DDC

Like the results of the interviews and surveys for the LCC, participants generally agreed with each other that they do not find the DDC to be very useful. For all three criteria, participants responded very critically. Question 4, relating to the DDC structure, was of particular interest, due to the high percentage of participants who questioned the accuracy of the structure.

OCLC (n. d.) calls the DDC a general knowledge organization tool. It is the most widely used classification scheme in the world (OCLC) and is very popular among primary and secondary school libraries as well as public libraries. These libraries, while they do vary in size, often do not need the level of detail that an academic researcher might need. This helps to explain the significant percentage of interview response items that are critical of the level of detail of the DDC. Also, the DDC faces difficulties in staying current, similar in nature to the LCC scheme's challenges.

Mathematics Subject Classification

Contrasting the feelings of participants to the other classifications, participants were very accepting of the Mathematics Subject Classification. For all three criteria, participants praised the MSC. Where there were some dissenting remarks, overall, the responses were very positive.

As mentioned in the results chapter, it can be inferred that the participants find that the level of detail is the strongest attribute of the Mathematics Subject Classification. The researcher suggests one of the reasons that the participants were highly complimentary of the level of detail is that a high level of detail, according to Foskett (1982), likely leads to high relevance for a person searching media using a classification.

While the LCC notion was liked by the participants, the MSC notation gained an even wider acceptance, with five participants marking "Strongly agree" to the survey. Sayers (1955), Vickery (1975), and Foskett (1982) all allude to the idea that brevity (characteristic of the MSC notation) is a requirement for good notation. Sayers and Foskett also allude to the advantage of flexibility in notation, something that several participants mentioned in their responses when complimenting the MSC. A few participants do suggest that the MSC scheme, even with its flexible nature, may need to be even more flexible to accommodate the ever-changing field, especially in interdisciplinary areas.

Several participants mentioned the authoritativeness of the MSC. One participant compared the MSC to a language, in that mathematicians share the MSC as a sort of language for their community. This idea relates to the fifth of Richardson's (1935) criteria, that the generalness of use of a classification adds to its value. While this study focused on the first three of Richardson's criteria, the findings of this study also help to support the validity of Richardson's fifth criterion.

The researcher suggests that the level of involvement by mathematics experts in the development of the MSC scheme is the single most important factor in its acceptance by participants. This agrees with McIlwaine (1991), who stressed the importance of collaboration between classifiers and information users. The persons designing this classification, by collaborating with mathematics experts, have the ability to gain an understanding of, not only trends in publication, but of needs such as the level of detail and even the construction of the notation. Changes can be made proactively to the needs of the profession.

Implications of this Study

For Classification Designers

Several participants offer suggestions for improvement of the classifications, especially for LCC and DDC. Participants strongly recognize the need for collaboration between classification designers and experts in the field. The researcher recognizes that while many persons use libraries and these classifications besides mathematics professors, the mathematics professors are experts, with current knowledge of trends in the field.

Also for the LCC and DDC, participants had strong concerns about the level of detail presented in those classifications. Some participants repeatedly mentioned a need for more subcategorization in specific fields and others mentioned key topics that were simply missing from the classifications. Referring to the previous paragraph, classification designers may help alleviate this by an increased level of cooperation with the field, including professional associations such as the American Mathematical Society.

Participants, especially for the MSC, refer to the flexibility of the notation for the future. The participants like the idea that the MSC skips classification numbers, allowing for insertion of numbers between the currently existing topics. More than one participant, however, had concerns about notation for interdisciplinary fields, which some participants see as the most exciting and quickly growing fields within mathematics. One participant suggested that some sort of new notation would be necessary that would allow for interdisciplinary topics.

For Librarians

Participants mentioned repeatedly that mathematics is a complex and changing subject. One participant identified that he feels that catalogers are too quick to classify an item using a broad level of classification when a narrower level of classification is available. The choice of the narrowest applicable term for all three classifications would appear to be the best option. The changing nature of the field would lead to the suggestion that catalogers be diligent in updating the classification and shelf location of items.

Another of the themes commonly given by participants was the authoritativeness of the MSC. By becoming familiar with the MSC, an academic librarian who serves as a subject specialist can develop a picture of how mathematicians view the field. A person making purchasing decisions might use the MSC to identify gaps in coverage when comparing to the emphases of the mathematics department of the university in question. This same procedure can be completed with any of the three classifications in this study; however, the completeness and authoritativeness of the MSC offers a unique alternative to LCC or DDC in this effort.

Some library catalogers have already begun using the MSC in MARC records for monographs and journals to supplement other subject headings, such as the Library of Congress Subject Headings. Depending upon the scope of the item, a cataloger may choose more than one MSC heading. The cataloger may also use only the two-digit (section) or three-digit (sub-section) portion if the situation warrants, but as mentioned before, the narrowest applicable term and notation is preferred. Catalogers using MARC21 can use the 084 "Other class numbers" tag to specify the MSC notation.

For Mathematics Experts and for Other Library Users

As these classifications improve, mathematics experts, including mathematics professors such as the participants in this study, will ultimately see the benefit of classifications that better meet their needs. This study is also an informative tool, allowing mathematics experts, librarians, and the general public to see the strengths and weaknesses of each classification. This might encourage mathematics experts to push for changes to the classifications when deemed necessary. Collaboration, in the view of the researcher, can only help to improve mathematics subject classifications.

Extensions for Future Research

The researcher suggests several areas for future research. This study, and any of these future extensions, help to answer Kuhlthau's (2005) call for LIS studies that have interests to more than one area of the field. The research extensions suggested below all entail both user studies and research in classification.

The first possible extension is to expand the scope of this study to a larger criteria set, perhaps using all five of Richardson's (1935) criteria, a larger participant pool of mathematics professors, more classification schemes (such as the Universal Decimal Classification), and more extensive data analysis.

The second possible extension would be to identify a different participant pool. One participant of this study suggested that the researcher interview mathematics graduate students. Naturally, undergraduate mathematics majors would be another possible participant pool. Finally, a mixture of undergraduate students, graduate students, and professors may be possible. Outside of a university environment, one could interview public school mathematics teachers who may have more familiarity with the DDC. Alternatively, one could choose a participant pool outside of mathematics. One possible option would be librarians. This might include a group of catalogers, subject specialists, or reference generalists.

Another possible area of research would be in a separate field. One could repeat this study, but choose another scientific discipline, such as physics or medicine, or a field in the humanities. Subject classifications exist for many disciplines on a national or international level.

Conclusions

The researcher is hopeful that academic libraries will give continued and increased consideration to practices and policies concerning classification schemes for all academic fields, but especially in the field of mathematics. The participants agree in their dislike of the DDC. The researcher, while recognizing that mathematics professors are not the only users of academic libraries, suggests that academic libraries using the DDC strongly consider other alternatives, such as including MSC numbers in bibliographic records, or giving serious consideration to a library-wide reclassification to the LCC.

The findings of this study strongly emphasize McIlwaine's (1997) call for collaboration between classification designers. Collaboration helps classification designers understand more intimately the needs of information users. Being proactive about trends in the mathematics field leads to better, more current classifications schemes.

The researcher also cautions persons designing classifications. As Bowker and Star (1999) suggest, there exist limitations in the involvement of information users when designing classifications. The researcher suggests that both experts in information science as well as the information users are needed to create an excellent classification. While information users bring specialized subject knowledge, experts in information science bring classification design knowledge and experience. The researcher argues that both parties are needed. Additionally, the researcher recognizes that there may exist many user groups for a classification and that input may be desired from many user groups. For example, graduate students, undergraduate students, and private researchers are all persons who might use mathematics subject classifications and who may have their own specialized needs.

The researcher also encourages other LIS researchers to answer Kuhlthau's (2005) call for research that involves more than one area of library and information science. The researcher especially encourages those researchers who perform information user studies to continue and expand their work in this area. The researcher feels strongly about the user-centered nature of the library and information professions and hopes that through user studies, the profession can increasingly customize our services to meet our clientele's needs.

Also, the researcher is hopeful that this study will lead to improved classifications in the mathematics field. As established in the introduction to this study, Vickery (1975) stated that the value of classification is nearly universal in the field of information storage and retrieval. By improving the mathematics classifications, their value can increase, benefiting librarians, mathematics experts, and other library users.

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Appendix A

APPLICATION FOR APPROVAL TO USE HUMAN SUBJECTS

For R&G Use Only	Date approved ________	Approved by ________	
Protocol No. ______	Full Review ______	Expedited Review ______	Exempted Review ______

This application should be submitted, along with the Informed Consent Document and supplemental material, to the Institutional Review Board for Treatment of Human Subjects, Research and Grants Center, Plumb Hall 313F, Campus Box 4003.

This form must be typed. This form is available online at www.emporia.edu/research/docs/irbapp.doc.

1. Name of Principal Investigator(s) (Individual(s) administering the procedures):
   Jeff Bond, MLS student

Mirah Dow, Jim Nyce, Marvin Harrell, thesis committee

THIS IS A DUPLICATE SUBMITION. The first sent in ESU campus mail seems to be missing.

2. Departmental Affiliation: School of Library and Information Management

3. Person to whom notification should be sent: Mirah Dow
   Mailing Address: Campus Box 4025

   Telephone: 620-341-5734 Email address: mdow@emporia.edu

4. Title of Project:

The Use and Evaluation of Three Mathemathics Subject Classifications By Mathematics Professors: A grounded theory study

5. Funding Agency (if applicable): none at this time

6. This is a: _____dissertation X thesis _____class project _____other research study

7. Time period for which you are requesting approval (maximum one year): from 20061 to 20071. *If the research project extends past the end date requested, you will need to submit a request for a time extension or an annual update. This form is available at www.emporia.edu/research/docs/irbmod.doc.*

8. Project Purpose *(please be specific)*:

This thesis is a user study of mathematics professors, who currently perform research in one or more fields within mathematics. The purpose of this study is to identify strong and weak characteristics of mathematics subject classifications, specifically the Dewey Decimal Classification, the Library of Congress Classification, and the American Mathematical Society Mathematics Subject Classification.

9. Describe the proposed subjects: *(age, sex, race, expected number of participants, or other special characteristics, such as students in a specific class, etc.)*

Mid-western university mathematics professors

10. Describe how the subjects are to be selected. *If you are using archival information, you must submit documentation of authorization from applicable organization or entity.*

Dr. Marvin Harrell, a member of the thesis committee, has identified three individuals (a mathematics professor at each of three universities), to assist in identifying participants. These persons are providing names of participants based on the criteria of diversity of mathematics expertise, interest in library classifications, and availability of the participants. The researcher and his committee will make the final decision on the final participant list, also based on the above criteria.

11. Describe **in detail** the proposed procedures and benefit(s) of the project. This must be clear and detailed enough so that the IRB can assure that the University policy relative to research with human subjects is appropriately implemented. Any proposed experimental activities that are included in evaluation, research, development, demonstration, instruction, study, treatments, debriefing, questionnaires, and similar projects must be described here. **Copies of questionnaires, survey instruments, or tests should be attached.** (*Use additional page if necessary.*)

Please see research proposal with survey and interview protocol.

12. Will questionnaires, tests, or related research instruments not explained in question #11 be used?
_____ Yes __X__ No (*If yes, attach a copy to this application.*)

13. Will electrical or mechanical devices be applied to the subjects? _____Yes __X__ No (*If yes, attach a detailed description of the device(s) used and precautions and safeguards that will be taken.*)

14. Do the benefits of the research outweigh the risks to human subjects? __X__ Yes _____ No (*If no, this information should be outlined here.*)

15. Are there any possible emergencies which might arise in utilization of human subjects in this project?
_____ Yes __X__ No (*If yes, details of these emergencies should be provided here.*)

16. What provisions will you take for keeping research data private/secure? (*Be specific -- refer to p. 3 of Guidelines.*)

No actual names will be used to identify the data. Each participant interview will be recorded on microcassette, and will also complete a survey and the informed consent document. The microcassettes and surveys will not have the participants' names on them, but will be identified with a unique identification number. The signed informed consent documents will be separated from the other materials. The researcher will keep a list of the identification numbers and participant names in a password-protected location on a personal computer. These data will be kept in a secure place out of reach from the public and will be destroyed once the thesis is written and approved.

17. **Attach a copy of the informed consent document, as it will be used for your subjects**. attached

INVESTIGATOR'S ASSURANCE: I certify that the information provided in this request is complete and accurate. I understand that as Principal Investigator I have ultimate responsibility for the protection of the rights and welfare of human subjects and the ethical conduct of this research protocol. I agree to comply with all of ESU's policies and procedures, as well as with all applicable federal, state, and local laws regarding the protection of human subjects in research, including, but not limited to, the following:

- The project will be performed by qualified personnel according to the research protocol,
- I will maintain a copy of all questionnaires, survey instruments, interview questions, data collection instruments, and information sheets for human subjects,
- I will promptly request approval from ESU's IRB if any changes are made to the research protocol,

- I will report any adverse events that occur during the course of conducting the research to the IRB within 10 working days of the date of occurrence.

Jeff Bond
Signature of Principal Investigator

April 25, 2006
Date

FACULTY ADVISOR'S/INSTRUCTOR'S ASSURANCE: By my signature on this research application, I certify that the student investigator is knowledgeable about the regulations and policies governing research with human subjects and has sufficient training and experience to conduct this particular study in accord with the approved protocol. In addition,

- I agree to meet with the student investigator on a regular basis to monitor study progress,
- Should problems arise during the course of this study, I agree to be available, personally, to supervise the principal investigator in solving them,
- I understand that as the faculty advisor/instructor on this project, I will be responsible for the performance of this research project.

Mirah Dow
Faculty advisor/instructor on project (if applicable)

April 25, 2006
Date

Appendix B

Informed Consent Document

The School of Library and Information Management at Emporia State University supports the practice of protection for human subjects participating in research and related activities. The following information is provided so that you can decide whether you wish to participate in the present study. You should be aware that even if you agree to participate, you are free to withdraw at any time, and that if you do withdraw from the study, you will not be subjected to reprimand or any other form of reproach. Likewise, if you choose not to participate, you will not be subjected to reprimand or any other form of reproach.

Only essential information to the study will be gathered. Personally identifiable information will be destroyed upon the completion of the study.

Please contact Jeffrey D. Bond, graduate student, at 620-794-3390, or Mirah Dow, PhD, Assistant Professor at 620-341-5734, at Emporia State University, if you have concerns about this study.

This thesis is a user study of mathematics professors, who currently perform research in one or more fields within mathematics. This purpose of this study is to identify strong and weak characteristics of mathematics subject classifications, specifically the Dewey Decimal Classification (DDC), the Library of Congress (LC) Classification, and the American Mathematical Society Mathematics Subject Classification (MSC). The results of this user study may be of use to designers of the above mathematics subject classifications, as well as designers of other mathematics subject classifications. The results will also be of use to academic librarians, especially those who regularly assist mathematics professors, and who share overall responsibility for policies and practices that are established and implemented by librarians regarding the creation, organization, use, and knowledge contained within libraries.

Mathematics subject classifications will be investigated on the basis of the usefulness of notation, accuracy of the semantic relationship structure, and appropriate level of specificity. This study uses both a survey and open-ended interview questions to identify the participants' perceptions of the classifications.

For each participant selected, the researcher will gather information from the expert committee to identify the participant's specific area of expertise. Using this information, the researcher will copy a corresponding subsection from each of three classifications for use in the participant interview. The researcher will prepare three survey questions and three open-ended interview questions for each participant.

The researcher will conduct a face-to-face interview with each participant. The researcher will give the participant one of the classification subsections. The participant will then answer three questions pertaining to the first classification subsection, and will answer three qualitative interview questions pertaining to the same subsection. This process will repeat for each of the two remaining classification subsections, for a total of nine survey questions and nine open-ended interview questions for each participant.

Data from interviews and surveys will be used to create a rich picture of the mathematics professors' perceptions of usefulness of the three classification schemes. Interview transcriptions will be analyzed using an analytic-inductive process as inspired by grounded theory techniques (Strauss, 1998). Once transcribed, each participant will be asked to read and verify accuracy of his/her statements. Using an established content data analysis approach, interviews will be read and reoccurring themes coded. The researcher will use Excel to calculate frequency and percentage distribution of interview theme categories, and will use Statistical Package for Social Science software to determine statistical significance of survey responses. Both sets of data analysis will be reviewed and compared to clarify preferences, priorities, and concerns relevant to usefulness of notation, accuracy of knowledge structure, and appropriate level of specificity.

"I have read the above statement and have been fully advised of the procedures to be used in this project. I have been given sufficient opportunity to ask any questions I had concerning the procedures and possible risks involved. I understand the potential risks involved and I assume them voluntarily. I likewise understand that I can withdraw from the study at any time without being subjected to reproach."

____________________________ ____________________________

Subject Date

Appendix C

LCC Participant Excerpt Example

(Library of Congress Cataloging and Support Office, Library Services, 2004)

Note: The color was used as an identifier for survey purposes. Participant did not see the name of the classification or citation above.

Functional Analysis

QA 319	Periodicals, societies, congresses, serial publications
QA 320	General works
QA 321	Addresses, essays, lectures
QA 321.5	Nonlinear functional analysis
QA 322	Topological linear spaces
QA 322.2	Normed linear spaces. Banach spaces
QA 322.4	Inner product spaces. Hilbert spaces
QA 322.5	Indefinite inner product spaces
QA 323	Function spaces
QA 324	Theory of distributions
QA 325	Measures, integration, derivatives
QA 326	Topolological algebras. Banach algebras
	Operator Theory:
QA 329	General works
QA 329.2	Linear operators
	Differential operators:
QA 329.4	General works
QA 329.42	Partial differential operators
QA 329.6	Integral operators
QA 329.7	Pseudodifferential operators
	Nonlinear operators:
QA 329.8	General works
QA 329.9	Fixed point theory

Appendix D

DDC Excerpt Example

Mitchell, Beall, Martin, Matthews, & New, 2003)

Note: The color was used as an identifier for survey purposes. Participant did not see the name of the classification or citation above.

<u>Functional Analysis</u>

515.72	Operational calculus
515.722	Spectral and representation theories
515.722 2	Spectral theory
515.722 3	Representation theory
515.723	Transforms (Integral operators, integral transforms), including Fourier, Hilbert, Laplace, Legendre, Radon, Z transforms
515.724	Operator theory
515.724 2	Differential operators, including elliptic operators
515.724 6	Linear operators
515.724 8	Nonlinear operators
515.73	Topological vector spaces, including spaces of analytic functions, spaces of continuous functions, spaces of measurable functions, e.g., L^p spaces, Orlicz spaces, Hermitian (unitary) and Riesz spaces, linear topological spaces
515.732	Banach spaces, including normed linear spaces
515.733	Hilbert spaces, including inner product spaces
515.75	Functional equations
515.78	Special topics
515.782	Distribution theory, including duality, Sobolev spaces, generalized functions
515.785	Abstract harmonic analysis, including Fourier analysis on groups

Appendix E

MSC Excerpt Example

(American Mathematical Society, 2000)

Note: The color was used as an identifier for survey purposes. Participant did not see the name of the classification or citation above.

46–XX FUNCTIONAL ANALYSIS
46–00 General reference works (handbooks, dictionaries, bibliographies, etc.)
46–01 Instructional exposition (textbooks, tutorial papers, etc.)
46–02 Research exposition (monographs, survey articles)
46–03 Historical (must also be assigned at least one classification number from Section 01)
46–04 Explicit machine computation and programs (not the theory of computation or programming)
46–06 Proceedings, conferences, collections, etc.

46Axx Topological linear spaces and related structures
46A03 General theory of locally convex spaces
46A04 Locally convex Fr´echet spaces and (DF)-spaces
46A08 Barrelled spaces, bornological spaces
46A11 Spaces determined by compactness or summability properties (nuclear spaces, Schwartz spaces, Montel spaces, etc.)
46A13 Spaces defined by inductive or projective limits (LB, LF, etc.)
46A16 Not locally convex spaces (metrizable topological linear spaces, locally bounded spaces, quasi-Banach spaces, etc.)
46A17 Bornologies and related structures; Mackey convergence, etc.
46A19 Other "topological" linear spaces (convergence spaces, ranked spaces, spaces with a metric taking values in an ordered structure more general than R, etc.)
46A20 Duality theory
46A22 Theorems of Hahn-Banach type; extension and lifting of functionals and operators
46A25 Reflexivity and semi-reflexivity
46A30 Open mapping and closed graph theorems; completeness (including B-, Br-completeness)
46A32 Spaces of linear operators; topological tensor products; approximation properties
46A35 Summability and bases
46A40 Ordered topological linear spaces, vector lattices
46A45 Sequence spaces (including Köthe sequence spaces)
46A50 Compactness in topological linear spaces; angelic spaces, etc.
46A55 Convex sets in topological linear spaces; Choquet theory
46A61 Graded Fr´echet spaces and tame operators
46A63 Topological invariants ((DN), (Ω), etc.)
46A70 Saks spaces and their duals (strict topologies, mixed topologies, two-norm spaces, co-Saks spaces, etc.)
46A80 Modular spaces
46A99 None of the above, but in this section

46Bxx Normed linear spaces and Banach spaces; Banach lattices
46B03 Isomorphic theory (including renorming) of Banach spaces
46B04 Isometric theory of Banach spaces

46B07 Local theory of Banach spaces
46B08 Ultraproduct techniques in Banach space theory
46B09 Probabilistic methods in Banach space theory
46B10 Duality and reflexivity
46B15 Summability and bases
46B20 Geometry and structure of normed linear spaces
46B22 Radon-Nikodým, Kreĭn-Milman and related properties
46B25 Classical Banach spaces in the general theory
46B26 Nonseparable Banach spaces
46B28 Spaces of operators; tensor products; approximation properties
46B40 Ordered normed spaces
46B42 Banach lattices
46B45 Banach sequence spaces
46B50 Compactness in Banach (or normed) spaces
46B70 Interpolation between normed linear spaces
46B99 None of the above, but in this section

46Cxx Inner product spaces and their generalizations, Hilbert spaces
46C05 Hilbert and pre-Hilbert spaces: geometry and topology (including spaces with semidefinite inner product)
46C07 Hilbert subspaces (= operator ranges); complementation (Aronszajn, de Branges, etc.)
46C15 Characterizations of Hilbert spaces
46C20 Spaces with indefinite inner product (Kreĭn spaces, Pontryagin spaces, etc.)
46C50 Generalizations of inner products (semi-inner products, partial inner products, etc.)
46C99 None of the above, but in this section

46Exx Linear function spaces and their duals
46E05 Lattices of continuous, differentiable or analytic functions
46E10 Topological linear spaces of continuous, differentiable or analytic functions
46E15 Banach spaces of continuous, differentiable or analytic functions
46E20 Hilbert spaces of continuous, differentiable or analytic functions
46E22 Hilbert spaces with reproducing kernels (=[proper] functional Hilbert spaces, including de Branges-Rovnyak and other structured spaces)
46E25 Rings and algebras of continuous, differentiable or analytic functions
46E27 Spaces of measures
46E30 Spaces of measurable functions (Lp-spaces, Orlicz spaces, K¨othe function spaces, Lorentz spaces, rearrangement invariant spaces, ideal spaces, etc.)
46E35 Sobolev spaces and other spaces of "smooth" functions, embedding theorems, trace theorems
46E39 Sobolev (and similar kinds of) spaces of functions of discrete variables
46E40 Spaces of vector- and operator-valued functions
46E50 Spaces of differentiable or holomorphic functions on infinite-dimensional spaces
46E99 None of the above, but in this section

46Fxx Distributions, generalized functions, distribution spaces
46F05 Topological linear spaces of test functions, distributions and ultradistributions
46F10 Operations with distributions
46F12 Integral transforms in distribution spaces
46F15 Hyperfunctions, analytic functionals
46F20 Distributions and ultradistributions as boundary values of analytic functions
46F25 Distributions on infinite-dimensional spaces
46F30 Generalized functions for nonlinear analysis (Rosinger, Colombeau, nonstandard, etc.)
46F99 None of the above, but in this section

46Gxx Measures, integration, derivative, holomorphy (all involving infinite-dimensional spaces)
46G05 Derivatives
46G10 Vector-valued measures and integration

46G12 Measures and integration on abstract linear spaces
46G15 Functional analytic lifting theory
46G20 Infinite-dimensional holomorphy
46G25 (Spaces of) multilinear mappings, polynomials
46G99 None of the above, but in this section

46Hxx Topological algebras, normed rings and algebras, Banach algebras
46H05 General theory of topological algebras
46H10 Ideals and subalgebras
46H15 Representations of topological algebras
46H20 Structure, classification of topological algebras
46H25 Normed modules and Banach modules, topological modules
46H30 Functional calculus in topological algebras
46H35 Topological algebras of operators
46H40 Automatic continuity
46H70 Nonassociative topological algebras
46H99 None of the above, but in this section

46Jxx Commutative Banach algebras and commutative topological algebras
46J05 General theory of commutative topological algebras
46J10 Banach algebras of continuous functions, function algebras
46J15 Banach algebras of differentiable or analytic functions, Hp-spaces
46J20 Ideals, maximal ideals, boundaries
46J25 Representations of commutative topological algebras
46J30 Subalgebras
46J40 Structure, classification of commutative topological algebras
46J45 Radical Banach algebras
46J99 None of the above, but in this section

46Kxx Topological (rings and) algebras with an involution
46K05 General theory of topological algebras with involution
46K10 Representations of topological algebras with involution
46K15 Hilbert algebras
46K50 Nonselfadjoint (sub)algebras in algebras with involution
46K70 Nonassociative topological algebras with an involution
46K99 None of the above, but in this section

46Lxx Selfadjoint operator algebras (C*-algebras, von Neumann (W*-) algebras, etc.)
46L05 General theory of C*-algebras
46L06 Tensor products of C*-algebras
46L07 Operator spaces and completely bounded maps
46L08 C*-modules
46L09 Free products of C*-algebras
46L10 General theory of von Neumann algebras
46L30 States
46L35 Classifications of C*-algebras, factors
46L37 Subfactors and their classification
46L40 Automorphisms
46L45 Decomposition theory for C*-algebras
46L51 Noncommutative measure and integration
46L52 Noncommutative function spaces
46L53 Noncommutative probability and statistics
46L54 Free probability and free operator algebras
46L55 Noncommutative dynamical systems
46L57 Derivations, dissipations and positive semigroups in C*-algebras
46L60 Applications of selfadjoint operator algebras to physics

46L65 Quantizations, deformations
46L70 Nonassociative selfadjoint operator algebras
46L80 K-theory and operator algebras (including cyclic theory)
46L85 Noncommutative topology
46L87 Noncommutative differential geometry
46L89 Other "noncommutative" mathematics based on C*-algebra theory
46L99 None of the above, but in this section

46Mxx Methods of category theory in functional analysis
46M05 Tensor products
46M07 Ultraproducts
46M10 Projective and injective objects
46M15 Categories, functors
46M18 Homological methods (exact sequences, right inverses, lifting, etc.)
46M20 Methods of algebraic topology (cohomology, sheaf and bundle theory, etc.)
46M35 Abstract interpolation of topological vector spaces
46M40 Inductive and projective limits
46M99 None of the above, but in this section

46Nxx Miscellaneous applications of functional analysis
46N10 Applications in optimization, convex analysis, mathematical programming, economics
46N20 Applications to differential and integral equations
46N30 Applications in probability theory and statistics
46N40 Applications in numerical analysis
46N50 Applications in quantum physics
46N55 Applications in statistical physics
46N60 Applications in biology and other sciences
46N99 None of the above, but in this section

46Sxx Other (nonclassical) types of functional analysis
46S10 Functional analysis over fields other than R or C or the quaternions; non-Archimedean functional analysis
46S20 Nonstandard functional analysis
46S30 Constructive functional analysis
46S40 Fuzzy functional analysis
46S50 Functional analysis in probabilistic metric linear spaces
46S60 Functional analysis on superspaces (supermanifolds) or graded spaces
46S99 None of the above, but in this section

46Txx Nonlinear functional analysis
46T05 Infinite-dimensional manifolds
46T10 Manifolds of mappings
46T12 Measure (Gaussian, cylindrical, etc.) and integrals (Feynman, path, Fresnel, etc.) on manifolds
46T20 Continuous and differentiable maps
46T25 Holomorphic maps
46T30 Distributions and generalized functions on nonlinear spaces
46T99 None of the above, but in this section

Appendix F

Open-Ended Interview Questions

Note: These questions are repeated for each of three classifications.

1. Tell me about the accuracy of the knowledge structure in this classification.
2. Tell me about the effectiveness of the level of detail in this classification.
3. Tell me about the ease of use of the notation in this classification.

Appendix G

Participant Survey

Note: Colors match identifying colors on classification excerpts.

Circle the best answer to each question:

1. This classification accurately reflects the knowledge structure of this field of study.

Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	2	3	4	5

2. This classification uses an appropriate level of detail.

Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	2	3	4	5

3. For this classification, the notation is easy to use.

Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	2	3	4	5

---

4. This classification accurately reflects the knowledge structure of this field of study.

Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	2	3	4	5

5. This classification uses an appropriate level of detail.

Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	2	3	4	5

6. For this classification, the notation is easy to use.

Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	2	3	4	5

---

7. This classification accurately reflects the knowledge structure of this field of study.

Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	2	3	4	5

8. This classification uses an appropriate level of detail.

Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	2	3	4	5

9. For this classification, the notation is easy to use.

Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	2	3	4	5

Appendix H

Cover Letter without Mention of Bold-Face Type

Jeff Bond
1333 Merchant St. #107
Emporia, KS 66801

Dear Professor,

Thank you for allowing me to interview you regarding mathematics subject classifications, for my thesis project.

Enclosed is a copy of the transcript of the interview. If you have any corrections to the transcript, please feel free to mark directly on the transcript. Grammatical and spelling errors need not be fixed. Changes to content or meaning are the most important corrections.

You may send it to me via postal mail at the above address, or you are welcome to email me with any changes. Please refer to line numbers if you choose to email. My email address is jbond@emporia.edu.

Please return any corrections by June 25, 2006. I will assume that you will have no changes if I do not hear anything by that date.

Again, thank you for your participation in my thesis project.

Sincerely,

Jeff Bond

Appendix I

Cover Letter with Mention of Bold-Face Type

Jeff Bond
1333 Merchant St. #107
Emporia, KS 66801

Dear Professor,

Thank you for allowing me to interview you regarding mathematics subject classifications, for my thesis project.

Enclosed is a copy of the transcript of the interview. If you have any corrections to the transcript, please feel free to mark directly on the transcript. Grammatical and spelling errors need not be fixed. Changes to content or meaning are the most important corrections. You will notice some words in bold type-face. Those words were unclear on the tape, and need special attention.

You may send it to me via postal mail at the above address, or you are welcome to email me with any changes. Please refer to line numbers if you choose to email. My email address is jbond@emporia.edu.

Please return any corrections by June 25, 2006. I will assume that you will have no changes if I do not hear anything by that date.

Again, thank you for your participation in my thesis project.

Sincerely,

Jeff Bond

PERMISSION TO COPY STATEMENT

I, Jeffrey D. Bond, hereby submit this thesis/report to Emporia State University as partial fulfillment of the requirements for an advanced degree. I agree that the Library of the University may make it available to use in accordance with its regulations governing materials of this type. I further agree that quoting, photocopying, digitizing, or other reproduction of this document is allowed for private study, scholarship (including teaching) and research purposes of a nonprofit nature. No copying which involves potential financial gain will be allowed without written permission of the author.

Jeff Bond

Signature of Author

8-7-2006

Date

THE USE AND EVALUATION OF THREE MATHEMATICS SUBJECT CLASSIFICATIONS BY MATHEMATICS PROFESSORS: A GROUNDED THEORY STUDY

Title of Thesis

Doug Cooper

Signature of Graduate Office Staff

8-7-06

Date Received

original