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Disciplinary Differences in E-learning Instructional Design: The Case of Mathematics

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Abstract

Discipline is a vital, yet largely overlooked, factor in research on e-learning course design. This study investigated disciplinary differences in the instructional design of e-learning, by comparing how instructors of mathematics-related disciplines versus others: a) met the challenges of their discipline in e-learning and b) perceived the adequacy of course management systems (CMSs). Investigators used a two-phase method: a) qualitative telephone and interviews, and b) web-based questionnaires. Mathematics instructors suggested very different disciplinary challenges and corresponding e-learning solutions. Mathematics-related instructors were significantly less likely to view prevailing e-learning models and CMSs as well-suited to their discipline.

Résumé

« Discipline » est un facteur vital, bien que souvent oublié, dans la recherche sur la conception de cours en ligne. Cette étude s'intéresse aux différences disciplinaires dans la conception de cours en ligne, en comparant comment les formateurs dans les disciplines reliées aux mathématiques par rapport aux autres formateurs : a) rencontrent les défis de leur discipline dans les cours en ligne, et b) perçoivent l'à-propos de leur environnement numérique d'apprentissage. Les chercheurs ont utilisé une méthode en deux phases : a) des entrevues au téléphone, et b) des questionnaires sur le Web. Les formateurs en mathématiques suggèrent des défis disciplinaires et des solutions en ligne très différentes. Les formateurs dans les disciplines reliées aux mathématiques étaient significativement moins susceptibles de considérer les modèles en ligne courants et les environnements d'apprentissage numériques comme bien adaptés à leur discipline.

Introduction

Which discipline—mathematics, English literature, nursing or education—is a vital factor in designing an e-learning course. Yet discipline is often overlooked in research on the instructional design of e-learning. Many e-learning research paradigms focus on constructs that cut across disciplines, perhaps implicitly downplaying disciplinary differences. The current study investigated the significance of discipline as a factor in the instructional design of e-learning. This study compares how instructors of mathematics and mathematics-related disciplines compare to instructors of other disciplines in how they meet the challenges of their discipline in e-learning, and how they perceive the adequacy of course management systems.

Review of Literature

Although there is a strong research interest in the instructional design of e-learning, a review of the literature revealed a relative absence of discipline in studies on this topic. Lee, Driscoll, & Nelson (2004) conducted a meta-analysis of research topics of the four most influential distance education research journals for the years 1997 to 2002. They reported a large number of keywords relating implicitly to 'instructional design.' Twenty-seven percent of the articles focused on 'design topics', 'needs assessment,' 'course scheduling,' 'course design,' 'instructional strategy development,' 'course material design,' or 'visual design.' However, there was no mention of 'discipline,' or anything roughly similar to 'discipline.' The following sections look at literature that peripherally relates to discipline in e-learning instructional design, as well as literature that directly addresses discipline.

Constructs Peripherally Relating to Discipline

Some research on instructional design of e-learning, while not explicitly citing discipline differences, uses constructs, such as "content," "curriculum," or "structure," which relate peripherally to discipline.

MacDonald et al. (2001) outline a demand-driven e-learning model for web-based learning with five main components: 1) superior structure, 2) learner, 3) content, 4) delivery, and 5) service. They suggest that 'content' should be comprehensive, authentic, industry-driven, and well-researched. Within their discussion of structure, they discuss "basing curriculum design on program goals" (p. 25) and suggest "breaking the goals down into relevant subject areas that determine course content" (p. 25).

Some researchers have suggested "curriculum" as a key element in the design of web-based courses (Berge, 1998; Driscoll, 1998; Meyen, Tangen, & Lian, 1999; Wiens & Gunter, 1998). However, curriculum is a subset of discipline. Discipline is an entire academic area and has traditional and immutable aspects derived from research and practice. Curriculum is a planned sequence of courses, things which are taught and given to pupils to be learned, or a set of values, skills, and beliefs which are available in a particular environment to be learned (Huebner, 1976; Johnson, 1969; Smith, 1976a, 1976b). Curriculum changes over time as approaches to teaching and learning change, while the walls of discipline remain more constant.

The notion of pedagogical content knowledge cuts to the heart of what it is about the content of a discipline that makes it difficult to teach. Shulman's (1986) seminal paper suggests three categories of content knowledge: a) subject matter content knowledge, b) pedagogical content knowledge, and c) curricular knowledge. "Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult," (Shulman, 1986: 7). There are two issues with the pedagogical content knowledge research literature that prevent it from being directly applicable to the topics of the current paper. First, pedagogical content knowledge is mostly discussed in the context of how K-12 teachers and pre-service teachers teach a particular content area. With the exception of colleges of education, pedagogical content knowledge is not usually discussed in the context of how college faculty teach their content. Secondly, although there have been some isolated studies emphasizing the role of discipline in e-learning (for example White and Liccardi (2006), Luebeck, & Bice (2005), Smith, Ferguson & Gupta (2004) and others), pedagogical content knowledge has not become as prominent in the research literature of college-level e-learning as its importance might warrant.

Research Addressing Discipline in E-learning

The attrition rate in online mathematics courses is significantly higher than for other disciplines (Smith & Ferguson, 2005). However, mathematics does not have a higher attrition rate than other disciplines in traditional face-to-face (f2f) courses. Common Course Management Systems (CMSs) fail to meet the basic needs of online college-level mathematics courses in terms of providing two-way communication of mathematics notation and diagrams between instructors and students (Smith et al., 2004). Smith et al. suggest that CMSs tend to favor text-oriented disciplines, and do not work as well for diagrams and other visual representations.

Although focusing on e-learning elements within hybrid and blended courses, White and Liccardi (2006) take a similar position to the current authors, and to Smith et al. (2004), in emphasizing the importance of discipline in e-learning design. They propose that instructors take a disciplinary perspective. Rationale for this approach uses Biglan's (1973) Taxonomy of Academic Disciplines as shown in Table 1 (partial, from White & Liccardi: 6).

Table 1. Biglan's Taxonomy of Academic Disciplines

	Hard	Soft
Pure	Natural Sciences (Content typically fixed and cumulative, and quantitative)	Social Sciences, Humanities (Non-linear, open and loose)
Applied	Engineering (Focus is on products and techniques. Knowledge is atomistic and cumulative, emphasizes factual understanding)	Nursing, Education (Concerned with the enhancement of professional practice. Knowledge is reiterative and holistic.)

To investigate the applicability of this conceptual framework to e-learning, White and Liccardi surveyed students' perceptions of the usefulness of specific e-learning methods in their area of academic study. Students in hard areas valued methods that reinforced facts, principles and concepts. Students in soft areas valued methods "that support the development of argumentation skills and critical thinking" (5). White and Liccardi approached students face-to-face, to survey them about e-learning. In asking on-campus students about e-learning techniques, no distinction was made between e-learning elements of hybrid, blended, web-enhanced courses, versus fully online courses.

Gaps In the Research

Although isolated practitioners and researchers have discussed the needs of their own discipline in isolation; e-learning and distance learning researchers have not compared e-learning across different disciplines from the point of view of the instructor. Within the broader field of distance learning and e-learning research, the single exception is White and Liccardi (2006). However, White and Liccardi (2006) focus on e-learning elements in hybrid, blended and web-enhanced courses. They also focus exclusively on the student viewpoint. Discipline has not been analyzed as a factor in fully online e-learning. Moreover, discipline has not been analyzed as a factor in how instructors approach e-learning design.

Research Questions

To address these issues, the current study investigated the following research question: To what extent is discipline a factor in how faculty approach the instructional design of fully online e-learning courses?

To operationalize the issue of discipline in e-learning, and to make it more salient, the investigators chose several discipline clusters, mathematics-related versus nursing/health-care versus other disciplines. This paper, focusing on mathematics and comparing it to other disciplines, is one of two sibling papers drawn from the current program of studies. A sibling paper by the same first author focuses on nursing and compares it to all other disciplines. A single paper analyzing and comparing mathematics, nursing/health-care to other disciplines would be cumbersome, and lacks sufficient detail to meaningfully cover the vital issues for each of these discipline clusters. However, a focus on mathematics, with a comparison to nursing and to all other disciplines can cover most the vital areas of discipline-related e-learning differences related to mathematics in an accessible, meaningful manner. Thus, this study investigated: a) how do mathematics-related disciplines compare to nursing and other disciplines when delivered online? b) how do online math-related instructors versus other disciplines solve the challenges of their discipline through e-learning? and c) how do online instructors, math/math-related versus all others perceive the adequacy of the current CMSs and e-learning models to address the needs and challenges of their discipline?

Method

The researchers employed a two-phase mixed method approach; the first phase qualitative, the second more quantitative. The first phase, using telephone and face-to-face (f2f) interviews, was exploratory; the investigators uncovered issues, and generated and refined questions. The second phase, using web-based questionnaires, allowed for a larger sample and the confirmation of some hypotheses uncovered in the first phase.

The first phase consisted of 20 interviews (see Table 2). The disciplines most represented were Mathematics (7 interviews) and Health Care (9 interviews). Other interviewees represented the fields of Music and Nursing.

Table 2. Number of Interviews by Discipline in the Qualitative Phase (Phase I)

Discipline	Number of Interviews
Mathematics	7
Music	1
Nursing/Health Care	9
Instructional Designers	3
Total	20

Table 3. Number of Interviews by Discipline in the Online Survey Phase (Phase II)

Discipline	Number of Interviews
Business	10
Counseling	1
Criminal Justice	1
Education	6
Engineering	11
ESOL	1
General	1
Health	2
History	2
Human Services	1
Mathematics	5
Nursing	7
Public Safety	1
Science	3
Social Science	8
Total	60

The second phase yielded 60 valid online responses. Table 3 shows the disciplines represented.

Qualitative Phase

Since the investigators wanted to use qualitative methods to investigate specific questions about the role of different disciplines in e-learning, they employed analytic induction (Becker, 1963; Bogdan & Biklen, 1992; Denzin, 1977; McCall & Simmons, 1971). In the current study, the authors wanted to answer questions about the unique teaching challenges that particular disciplines pose and how those challenges are met through e-learning.

The authors generated a list of open-ended questions and interviewed 20 online instructors from a variety of disciplines (see Table 2). As ascertained by a few preliminary questions (e.g., "how many face-to-face and online courses have you taught in your discipline?"), these online instructors had experience teaching both online and face-to-face in a range of different situations, i.e., different populations, courses and geographical areas. Initial email contact was made through professional contacts and then through the participants providing contact information for other experienced instructors, i.e., snowball sampling.

The initial open-ended interview questions were as follows:

1) What are the unique challenges of teaching your discipline across all teaching modalities (whether face-to-face, e-learning, or point-to-point distance, etc.)?

2) How do instructors in your discipline address the unique challenges and pedagogy in the e-learning environment?

3) What unique learning opportunities for your discipline does the e-learning modality afford, which are not available face-to-face?

4) What are the important issues of assessment of your discipline in e-learning?

5) What critical insights into teaching your discipline via e-learning were not covered by the preceding questions?

The interviews averaged approximately 45 minutes. The interviews were taped, transcribed, segmented and coded by two researchers. Inter-rater reliability between the coding of the two researchers was 84.6%.

Quantitative Phase

In order to expand the sample size and quantitatively test hypotheses generated in the first qualitative phase of the study, phase two employed an online survey with open-ended questions and Likert scale questions.

Instrument

The web-based survey used to collect data from online instructors consisted of 15 questions: nine open-ended questions and six Likert scale questions or multiple choice questions . See Appendix A for the complete questionnaire.

Data Collection

Online instructors were approached by email. The instructors were contacted through: a) email address lists manually compiled from the web sites of non-profit e-learning organizations that administer online courses for universities and colleges, and b) networking with professional acquaintances, such as online instructional designers who forwarded emails to instructors within their organization. The number of valid responses was 60. Participants were instructors of online courses from a variety of research one universities, four year colleges, and community colleges in the states of New York and Florida.

Data Analysis

The open-ended questions in the online interviews were analyzed in a manner similar to the phone and face-to-face interviews. The written responses were: 1) segmented, 2) coded, and 3) analyzed with the whole interview as the unit of analysis (IUA), i.e., which codes occurred at least once in the interview. In IUA, multiple occurrence of a code did not add to its frequency. IUA frequency was counted by the number of interviews in which a code appeared at least once. Consistent with the goals of analytical induction, this provided an overview identifying which themes were most common across interviews for particular parts of the sample.

The Likert scale questions were analyzed statistically, with particular attention to the comparison of different discipline groups, such as mathematics-related versus non-mathematics related.

Results

Results from Interviews (Phase 1)

All the mathematics instructors interviewed had extensive teaching experience, with a range of 10-25 years in the field. All had taught at least three unique mathematics courses online. Therefore, it is assumed that their comments about teaching mathematics online came, not as a reaction to a learning curve with the technology, but from a position of experience teaching mathematics online.

Mathematics instructors were remarkably consistent in describing what they perceived as the unique challenges of teaching mathematics. These challenges are reflected in Table 4, which shows the most common themes when analyzing interviews as the unit of analysis (number of interviews containing a particular code).

Table 4. Mathematics—Frequency of Codes/Themes Using Interview as Unit of Analysis

Code	Frequency	Percentage
abstract concepts	7	100%
sequential	7	100%
Problem solving	6	86%
symbols	6	86%
Visuals	6	86%
Need more "channels"	5	71%
more work	5	71%
academic integrity	5	71%
CMS	5	71%
feedback	5	71%
tech issues	5	71%
Tools	5	71%
motivation	4	57%
reviewable	4	57%
student attributes	4	57%
student control	4	57%

The challenge of teaching abstract concepts and the sequential nature of mathematics (each section building on the previous) appeared in all the interviews with mathematics instructors. Modeling problem solving, difficulties communicating online with mathematical symbols, and communicating visual diagrams appeared in 86% of the interviews.

Challenges of Teaching Mathematics

Online instructors elaborated at length on the following as the unique challenges of teaching mathematics: 1) abstract concepts, 2) sequential nature of mathematics, 3) the need for instructor modeling of problem-solving, 4) visual-spatial components, 5) the use of a unique set of symbols and notation and 6) academic integrity. The following paragraphs elaborate these six points.

One instructor describing the abstractness stated that: "It [mathematics] is a highly visual discipline with highly abstract concepts" and a major challenge for students is "understanding abstract concepts and being able to apply them to solve problems." However, also identified was "the lack of easily explained 'real life' examples in some courses [that] makes it less relevant to students' lives or chosen studies." Moreover, another instructor stated that "one of the biggest challenges as a math educator has always been that a lot of our kids do not think as mathematicians think or as math teachers think." Compounding the problem is that "mathematics is a 'foreign language' within a student's native language. Certain words in English have a very different meaning in Mathematics. For example the word 'or' in English usually means one or the other, but not both, i.e., what is called 'exclusive or' in computer science. In mathematics, 'or' is the 'inclusive or' (one of the other, or both)." Mathematics, says an instructor, "is different [from other disciplines] because the student has to construct concepts from previous concepts. This construction is done in a complex process of reflexive abstraction on mathematical objects."

The abstractness of mathematics has a number of implications for teaching. Students need to interact regularly to absorb the content. Mathematics textbooks cannot simply be read and understood. One online math instructor commented, "You have to sit down with paper and pencil and work through a mathematics textbook. You can't just read it." It is a challenge to get students at all levels to do their homework and to read the textbook with pencil and paper in hand. Math instructors commented that because mathematics is abstract, the "majority of [students] are math phobic. Half the students already have their mind turned off to what they have to learn."

Mathematics is sequential. Techniques build on earlier simpler formulations. An experienced math instructor said, "If you miss the bottom rung of the ladder, there is no way you are going to make it to the next one." Instructor modeling of problem-solving is a major part of mathematics pedagogy. Instructors and students derive problem-solving techniques from the basic concept and apply them to a range of problem situations (scientific and real-world phenomena).

Mathematics has a large visual-spatial component. Instructors typically draw diagrams on the board. Many instructors use models, paper fold-ups or other "manipulatives" to communicate a concept. Students watch the instructor solving problems based on the concept. Finally, students work such problems with copious instructor feedback.

Online mathematics instructors discussed academic integrity mostly in terms of tests and assessment, i.e., how did the instructor know it was really the student doing the work and how to eliminate unauthorized collaborations on assessments.

The mathematics instructors regarded the special challenges of teaching mathematics (discussed above) as crossing modality. The challenges of mathematics existed whether the class was face-to-face or online. For example, students need modeling of problem-solving whether they are taught face-to-face or online.

However, the mathematics instructors interviewed in the study suggested that in addition to the challenges of teaching mathematics in general, teaching mathematics through e-learning presented some new additional challenges, such as: a) lack of dynamism and b) problems with communicating diagrams and mathematics notation. Because of bandwidth limitations, asynchronous e-learning policies (many organizations stipulate all graded materials in online courses must be asynchronous) and the influence of CMSs, most documents in online courses are static text files that students read like pages of a textbook. This lack of dynamism presents a problem for online math instructors who need to model the problem-solving process for their students. Furthermore, instructors need to provide feedback to students working problems. The mechanisms for feedback within common CMSs emphasize text, not math notation nor diagrams. The recent addition of math-oriented tools to CMSs improves, but does not totally resolve the situation. For example, WebEQ in Blackboard allows both instructor and students to insert math notation, but enforces rigid syntax constraints, which is difficult for students to learn. Moreover, in Blackboard, there is no natural way to draw, copy, edit or annotate diagrams in asynchronous postings.

The investigators followed up the questions about the unique challenges to mathematics by asking the instructors how they met these challenges in the e-learning environment. In essence, the same six challenges of mathematics discussed above (1) abstract concepts, 2) sequential nature of mathematics, 3) the need for instructor modeling of problem-solving, 4) visual-spatial components, 5) the use of a unique set of symbols and notation, and 6) academic integrity were discussed in terms of how e-learning met those challenges, and what instructional strategies the instructors used to meet those challenges.

Dealing with abstract concepts through e-learning can be addressed as three subset parts: mathematics as a foreign language, sequential nature of mathematics, and modeling of problem solving. However, in terms of mathematics as a foreign language, most of the online mathematics instructors felt that the e-learning environment was not well suited to addressing this issue. In face-to-face courses, students are able to hear, and see (on the chalk board), the new "foreign language;" corrective feedback is provided and students are immersed in the foreign language. Within the online environment, there was less multi-modal immersion.

In meeting the challenge of the sequential nature of mathematics, online mathematics instructors suggested that e-learning is superior to face-to-face. Online instructors point out that, for review, they can refer students to external sites.

In terms of modeling of mathematics problem-solving for students, there are no easy solutions in e-learning. One inventive mathematics instructor incorporated an external math-friendly asynchronous (and synchronous) whiteboard system and used it to create "cooperative bulletin boards," where, for example, each student contributed one step, in a different color, to solving an equation. Thus students modeled problem-solving for each other. However, such inventiveness remains the exception. The lack of dynamism in asynchronous e-learning poses a great challenge for modeling the problem-solving process.

In terms of meeting the visuospatial and diagrammatic needs of mathematics, instructors felt the online environment to be woefully inadequate compared to the traditional classroom. Diagrams are a major part of mathematics and in the traditional face-to-face classroom, there is a potentiality of two-way diagrammatic communication. Instructors and students can both work problems and draw diagrams on the chalk board, overhead transparencies or with pencil and paper. The ability to communicate with diagrams, somewhat taken for granted in the traditional classroom, is exceedingly awkward in asynchronous e-learning. In asynchronous e-learning, online instructors and students communicate diagrammatically through an awkward use of attachments, uploading scanned hardcopy diagrams, or uploading diagrams created with various interactive programs. The process of attachments is multi-stepped and has none of the naturalness of the two-way text communication. It is also difficult to visually annotate student diagrams in e-learning.

Similar problems exist with the unique symbols and notation associated with mathematics. Online instructors and students cannot easily communicate with mathematics notation. Even though common CMSs provide some means for inputting mathematics symbols (such WebEQ), these tools are highly constrained, adding an inordinate cognitive load on online students who are already struggling with mathematics. Online instructors often resort to a variety of "workarounds," such as substitute notation systems using the available symbols on the keyboard and having students fax their work to instructors.

In terms of meeting the challenges of academic integrity and assessment issues, online mathematics instructors emphasized three issues: 1) new online interactive multi-media tools for mathematics assessment, 2) the use of proctored exams in math e-learning to ensure academic honesty, and 3) creative approaches to formative assessment.

Mathematics courses should include both formative and summative assessments. Publishing companies supply online assessment programs for formative assessment. Interactive multimedia tools, such as MyMathLab by Addison-Wesley Prentice Hall (2006), facilitate diagnostic assessment of incoming students and ongoing dynamic feedback. Online interactive assessments are excellent for day-to-day assignments; however, without effective verification of identity, the temptation to cheat is higher with exams. Text-oriented disciplines use services such as TurnItIn, numerically based courses, however, have no such validation system. Proctored exams may be administered by different resources (test centers, military officers, libraries, etc.) available to the distance education student.

Nursing/Health-Care Phase I Interviews

Although the phase I nursing interviews are discussed extensively in another paper, it is useful to note the broad differences between nursing/health-care and mathematics. A careful perusal of the nursing interviews revealed that assessment was not just the most common theme, but also united all the other common themes. For example, online nursing instructors discussed delivery methods, tools and academic integrity as part of their concerns about assessment. Assessment issues weaved their way through most of the interviews with online nursing instructors.

The most common themes across all the mathematics interviews relate to the challenges of mathematics (Table 4) while in nursing/health-care, the most wide-spread themes (Table 5) relate more to general online education, and might appear in many disciplines. Both groups, online mathematics instructors and online nursing/healthcare instructors, were asked the same initial questions, but their responses went in different directions. Core nursing undergraduate courses (clinical courses, with highly procedural skills) are usually not taught online, while "didactic", i.e., enrichment, nursing courses often are. Because human lives are at stake, nursing/health-care has largely opted out of delivering clinical/procedural skills with CMSs and online education. However, even with didactic courses, the stakes on assessment are still very great. Thus, concerns about assessment predominate.

In contrast, to meet the needs of returning adult learners working full-time, the undergraduate core mathematics courses (calculus, algebra, trigonometry, etc.) are taught online. Since CMSs are ill-suited to teaching core mathematics courses, online mathematics instructors have thought deeply about addressing the challenges of teaching mathematics through online education.

Results from Online Survey (Phase II)

Based on issues raised in the qualitative phase of the study, in analyzing the survey data, the investigators focused on two groups of online instructors: 1) mathematics and mathematics-related instructors, versus 2) all other instructors in the sample across disciplines.

Table 5. Nursing—Frequency of Codes/Themes Using Interview as Unit of Analysis

Code	Frequency	Percentage
Assessment	9	100%
delivery method	8	89%
Tools	8	89%
academic integrity	7	78%
Blended	7	78%
Feedback	7	78%
Interaction	7	78%
Authenticity	6	67%
CMS	6	67%
research sk	6	67%
student attributes	6	67%
tech issues	6	67%
>FLEX	5	56%
Orientation	5	56%
Sequential	5	56%

Table 6. Mathematics-related versus Other Disciplines—Descriptive Statistics of Response to the Question: "E-Learning Models and LMSs are Well-Suited to my Discipline"

	n	Response Mean	Std Dev
Math-related	16	2.94	1.44
All other	44	3.7	0.75

On average, the entire sample had taught 3.6 unique online courses. The mathematics and mathematics-related (primarily engineering) instructors represented 17 of the sample of 60. The math and math-related instructors had taught an average of 3.89 unique online courses. There were nine nursing/health care instructors in the sample who taught an average of four unique courses.

Most of the Likert style questions produced no significant differences between the two groups, mathematics versus all others. However, the mathematics and mathematics-related instructors felt significantly less satisfied with e-learning tools and models than their peers. On the question "are prevailing e-learning models and LMSs well-suited to my discipline?", there was a significant difference in mean responses between mathematics-related versus all other instructors.

Table 6 shows the means and standard deviations for this question. An ANOVA found this difference to be significant at the 0.01 level ($F(1,55) = 7.02$), with a medium effect size ($r = .34$). Note that mathematics-related instructors are much less likely than other online instructors to agree that e-learning models and LMSs are well-suited to their discipline.

This last significant result raises the question of whether the greater difficulties that online mathematics instructors have with e-learning tools are associated with amount of online teaching experience and with learning curves with the technology. Are novice online mathematics instructors (versus more experienced instructors) struggling more with LMSs? To attempt to answer this, the investigators ran correlations between: a) the number of unique e-learning courses instructors had taught, and b) variables such as how well e-learning models and LMSs were well-suited to their discipline. This correlation was non-significant for the sample as a whole. However, for math-related instructors, the correlation between number of unique e-learning courses taught and satisfaction with e-learning models was significant at the 0.05 level and quite large, .525. Figure 1 shows the histogram of math instructors' satisfaction with e-learning models. Note the bimodal shape of the histogram. Most of the mathematics instructors less experienced with

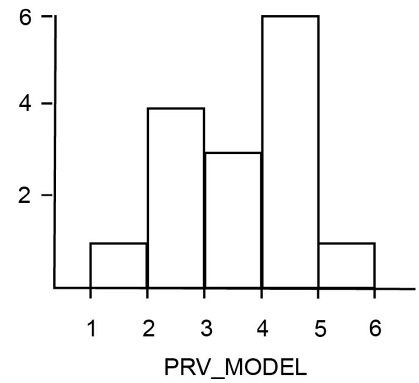

Figure 1. Mathematics-related Instructors—Prevailing E-Learning Models and LMSs are Well-Suited to my Discipline.

e-learning are on the left side of the histogram, i.e., math instructors less experienced with are e-learning are less satisfied with e-learning for mathematics. The same relationship is not true for the sample at large (Figure 2). Moreover, experience teaching face-to-face courses was not correlated with e-learning satisfaction, either for the mathematics instructors or the whole sample.

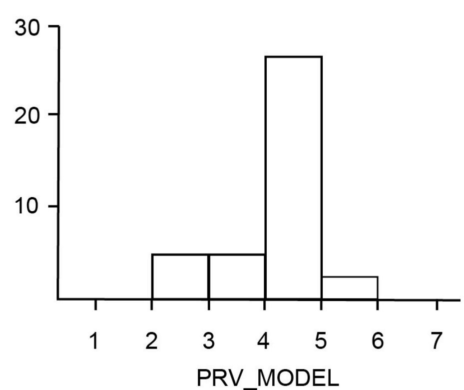

Figure 2. Figure 2: All Other Instructors—Prevailing E-Learning Models and LMSs are Well-Suited to my Discipline.

Analysis of Coded Responses with Interview as Unit of Analysis

The investigators also coded the responses to the open-ended questions in the phase II survey and analyzed that data with the interview as the unit of analysis (IUA). IUA frequency was the number of interviews in which a code appeared at least once.

Table 7 shows the most frequent codes in the phase II interviews by three discipline groups: mathematics-related, nursing/health-care and all others. This table shows a count of the number of interviews containing that theme. Mathematics and "all other" (left-most and right-most columns) share, in first and second positions, the themes of interaction and feedback. Nursing appears to be the exception with CMC (concerns with Course Management Systems) in first place. Descriptions of the codes are listed in Appendix B.

Table 7. Most Frequent Codes Appearing at Least Once in an Interview, with Percentages, by Discipline Group

Math-Related			Health			Other		
Code	Freq	Perc	Code	Freq	Perc	Code	Freq	Perc
interaction	9	56%	CMS	4	44%	feedback	23	66%
feedback	8	50%	ind hlp	3	33%	interaction	17	49%
student attributes	7	44%	acad. integrity	3	33%	academic integrity	13	37%
academic integrity	6	38%	feed-back	3	33%	asses-ment	12	34%
assessment	5	31%	perfor-mance sk	3	33%	<CHN	9	26%
symbols	5	31%	tech issues	3	33%	student attributes	9	26%
TM	5	31%	TM	3	33%	TM	9	26%
<CHN	4	25%	wr sk	3	33%	!ASYN	8	23%
slf rgl	4	25%	!ASYN	2	22%	slf rgl	8	23%
!ASYN	3	19%	>WK	2	22%	X	8	23%

It is also interesting to compare the most common themes in mathematics between phase I and phase II, i.e., to compare Table 4 and Table 7 (left-most column). For mathematics-related, the phase I interviews were more consistent than the online open-ended survey questions. In the phone/f2f interviews: two themes appeared in 100% of the interviews, three themes appeared in 86% of the interviews. In the online survey with open-ended questions, the most common theme appeared in only 56% of the interviews. The primary reasons for greater consistency in the phase I interviews were the longer length of the interviews, as well as follow-up questions to explore topics that seemed of most interest to the interviewees. Additionally, the mathematics instructors in the phase I interviews were uniformly experienced with e-learning, while the mathematics instructors in the phase II online survey had a range of e-learning experience. Nevertheless, four themes made the top ten mathematics lists in both phone/FTF and online surveys: feedback, student attributes, academic integrity, and symbols.

Discussion

Several important points emerged from the qualitative interviews in phase I. Within the two major discipline clusters there was remarkable consistency, while between discipline clusters there was little consistency. Common themes were consistent across mathematics interviews, common across nursing interviews, but distinctly different between mathematics and nursing. The online mathematics instructors focused on the challenges of teaching mathematics online, while the nursing instructors focused more on global issues of online education and assessment. This may be because core clinical (i.e., procedural) nursing courses are not generally taught online, while core mathematics courses are taught online. Moreover, online mathematics instructors have had to grapple with a mismatch between their discipline and common CMSs. Some of the challenges of teaching mathematics, such as its cumulative sequential nature, work better in the online environment. However, other mathematics teaching challenges, modeling of problem-solving, students working problems with feedback from instructors, require two-way communication in mathematics notation and diagrams, which is awkward in most CMSs.

The common themes across mathematics instructors differed from the phase I qualitative interviews versus phase II open-ended survey questions. This was probably the result of: a) math instructors in the qualitative sample having a more uniformly high level of experience with e-learning, than their peers in the online survey, b) methodological differences between the qualitative interviews and the online survey, and

c) informant mindsets. The interviews were considerably longer than the online survey. With more said face-to-face and by phone, more themes were covered and thus more themes shared. Phone/FTF interviews also give the interviewer flexibility to further pursue topics that informants cued as particularly important. This may suggest that interviewer knowledge of previous interviews can bias subsequent interviews. However, in the current study, there were three interviewers, so interviewer bias was minimized.

Another issue is the relative salience of "e-learning" versus "discipline" in the minds of online instructors. When asking an online instructor "what are the challenges of teaching your discipline through e-learning," "e-learning" may be more salient than "discipline." Since most instructors taught only within their discipline, differences between disciplines were not prominent. However, participating online instructors taught both face-to-face and online courses, and often wrestled with ways to convert content from face-to-face to online. In face-to-face/phone interviews, the interviewer could be persistent and drill for information. In open-ended questions in online surveys, the instructors answered according to their current mind set. More objective measures, such as the Likert scale question in phase II, were required. Thus, it is indicative that online open-ended questions did not reveal major differences between discipline clusters, while a Likert scale question on satisfaction with prevailing e-learning tools found mathematics instructors significantly less satisfied. Most of the other Likert scale questions revealed no such differences, suggesting that similarities in e-learning experiences outnumber the differences between disciplines. These differences, though small in number, may significantly affect faculty and students in those disciplines.

The open-ended online survey questions also revealed more similarities than differences in themes across discipline. For example "academic integrity" was common to all three clusters, mathematics-related, nursing/healthcare and other; while "interaction" and "feedback" were in the top two for mathematics-related and other. It is important to map out similarities and differences in e-learning approaches between different discipline clusters. Thus, upcoming studies will focus more on objective measures, such as analyzing which e-learning tools instructors use in different disciplines.

In the meantime, the current study identified certain disciplinary differences in e-learning. In the interviews, online mathematics instructors discussed a distinctively different set of themes than their peers in other disciplines. In the online survey, compared with other instructors, mathematics-related instructors were significantly less enthusiastic about current e-learning tools and models to meet the challenges of their discipline. Moreover, for mathematics instructors, satisfaction with e-learning was highly correlated with experience teaching online courses.

Common CMSs are notoriously poor in communicating mathematics notation and diagrams (Smith et al., 2004). The current authors wonder whether the struggles online math students (and instructors) have to communicate easily in mathematics notation and diagrams impose an extraneous cognitive load (Sweller, 1994) on top of the learning of mathematics. Ideally, technologies such as CMSs used for communication should be relatively transparent for two-way communication between instructor and student, or at least be less salient than the content. If e-learning environments are well-designed for a discipline, learner-interface interaction (Hillman, Willis & Gunawardena, 1994) should be minimized. Hillman et al. (1994) suggest that "the learner who is unskilled in interacting with the communications medium must dedicate the majority of his or her mental resources to retrieving the information, thus leaving fewer resources available for learning the lesson content."

For online mathematics (and mathematics-related) instructors, experience with e-learning definitely comes into play. Online mathematics instructors gradually adapt to combersome online communication tools. With experience teaching online, instructors also create their own solutions, dealing with the mismatch between e-learning and mathematics by eclectically assembling various online tools and resources (such as tools for real-time visual and auditory interaction), and also working very hard and creatively with common LMSs. Thus the online mathematics instructors who persist with teaching online often show a measure of pride in how they have adapted the technology to meet the needs of their students.

Conclusion

To put the current study into a larger context and provide readers with some final messages to take away, we now discuss: a) some possible new theoretical directions for e-learning and distance learning research, stemming from the current study, b) the practical implications for online instructional designers, would-be online instructors and current online instructors, and c) some logical directions for future studies.

New Theoretical Directions

The current authors believe that much of the research on distance learning and e-learning has been conducted and reported with a tacit assumption of the homogeneity of e-learning. The results of the current study strongly suggest that the demands and solutions of e-learning can be differentiated by disciplinary clusters. Perhaps e-learning and distance learning research should also be so differentiated by discipline.

The results of the current study inidicated that the concerns of experienced online mathematics instructors were very different than those of their nursing/healthcare peers. The mathematics instuctors were concerned with students learrning abstract concepts, the sequential nature of mathematics, modeling problem solving and the practical issues of online two-way communication in the language of mathematics (math symbols and diagrams). Moreover, online mathematics instructors - particularly less experienced online mathematics instructors - were far less satisfied with e-learning tools and models, than instructors from other disciplines. On the other hand, online nursing and healthcare instructors were much more concerned with authentic assessment, probably because of the serious ramifications of allowing unprepared nurses into hospitals. Furthermore, while core content of mathematics is routinely taught online; core content of nursing is rarely taught online.

This rather pragmatic evidence, suggests that e-learning is far from homogenous across disciplines. Perhaps various theoretical paradigms that have tacitly assumed e-learning to be homogeneous should be re-examined through the lens of discipline. For example constructs involving online interaction might be differentiated by discipline. Transactional distance (Moore, 1989, 1993) might be measured, for example, as per Sandoe (2005) in discipline clusters. Also, immediacy might be differentiated by discipline. Picciano's (2002) research on immediacy suggested that perceived social presence was correlated with perceived learning in online courses. Is this equally true for education courses versus hard science courses such as chemistry? Is transactional distance the same for physics courses as it is for English literature courses? The current authors suggest a program of research investigating the differences in e-learning between different disciplinary clusters, and extending the investigation of these disciplinary differences to various theoretical constructs. Such investigations might better differentiate elearning and also better elucidate the nature of the theoretical constructs.

Implications for Practice

The take-away message from the current study for online designers (those in training and those long in practice), and for online instructors (both novice and experienced) is that since the core content of each discipline cluster is different, so, too, should the e-learning solutions and instructional design be different. We know that face-to-face courses cannot be directly translated into e-learning with the expectation of success. However, beyond that, each discipline cluster has different type of content, with different pedagogical content knowledge that interacts with the e-learning modality. One may expect that certain disciplines may work more gracefully with the current e-learning tools than others. Before designing an online course, it is a good idea for novice online instructors and instructional designers to consult extensively with instructors and designers who are experienced within that particular discipline cluster. Further, over time, stake holders in various disciplines that work less well with prevailing e-learning tools should advocate strongly for improvement of these tools.

Directions forFuture Studies

Further studies in this program of research might investigate other disciplinary clusters. Such investigations might address disciplinary issues of instructor and instructional designer practice. Future studies could also investigate possible differentiation of theoretical constructs, along disciplinary lines. At any rate, the current study strongly suggests that "Which discipline" is a vital, yet largely overlooked, factor in research on e-learning course design.

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Appendix A—Survey Questions

Question	Type	Options
What academic discipline do you teach?	Open ended	
Approximately how many unique e-learning courses (not counting repeats) have you taught?	Open ended	

Approximately how many unique face-to-face courses (not counting repeats) have you taught?	Open ended	
How do you deliver courses online?	Multiple choice	Blackboard WebCT other LMS create own web pages or online environment Other (please specify)
What are the greatest difficulties facing learners in your discipline?	Open ended	
What pedagogies do you use in face-to-face courses to address these difficulties?	Open ended	
What pedagogies do you use in e-learning courses to address these difficulties?	Open ended	
What unique learning opportunities for your discipline does e-learning afford that are not available, or as convenient, in face-to-face situations?	Open ended	
The needs of learners and instructors in my discipline are well-met through e-learning.	Likert scale Neither	Strongly Disagree Disagree Agree Strongly Agree
What are the important issues of assessment of your discipline in e-learning?	Open ended	

Relative to teaching your discipline in e-learning, what can't you do that you would like to do?	Open ended	
There is a prevailing, generic model of e-learning associated with LMSs (Blackboard, WebCT, etc.) that largely ignores the differences between disciplines.	Likert scale	Strongly Disagree Disagree Neither Agree Strongly Agree
Prevailing e-learning models and LMSs are well-suited to my discipline.	Likert scale	Strongly Disagree Disagree Neither Agree Strongly Agree
Click all the elements your current e-learning course includes	Multiple choice	asynchronous synchronous online face-to-face other
I don't have synchronous online components, but my classes have a strong need for synchronous components.	Likert scale	Strongly Disagree Disagree Neither Agree Strongly Agree

Appendix B—Code Descriptions

Code	Description
!ASYN	asyn pro, asynchronous advantages, do it when feeling inspired, not during face-to-face class
<CHN	inadequacy of online environment to explain course content
>WK	> work—instructor spends more time online than face-to-face

academic integrity	issues of academic integrity
assessment	issues of assessment
CMS	Course Management System
feedback	instructor provided feedback
ind hlp	instructor provided individual help
interaction	promoted student interaction
performance sk	problems with performance skills
slf rgl	need for student self-regulation
student attributes	student characteristics, background
symbols	symbolic representation of math concepts
tech issues	technical issues
TM	time management
wr sk	problems with writing skills
X	greater explicitness of procedures, lectures online

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