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ABSTRACT

An alternative method of measuring the knowledge of students is to use mental models, and specifically concept maps. Concept maps provide a visual representation of conceptual and relationship knowledge within a particular domain. This study builds on previous studies and attempts to reduce their methodological weaknesses. Students in several undergraduate sections of an MIS Telecommunications course were asked to create concept maps of their Telecommunications knowledge at three distinct points throughout the semester. These concept maps were compared across all students at a single point in time, within students across the three time periods, and against the concept map of a domain "expert" at both the individual and composite levels. Findings indicate that the individual and composite maps increased significantly in size over time, and comparisons with the "expert" map show a significantly increasing overlap of concepts over time. Moreover, this study shows the applicability of this technique as an alternate assessment method. Includes seven tables and two figures. (Contains 12 references.) (Author)

CONCEPT MAPS AS AN ALTERNATIVE TECHNIQUE FOR ASSESSING STUDENTS' UNDERSTANDING OF TELECOMMUNICATIONS

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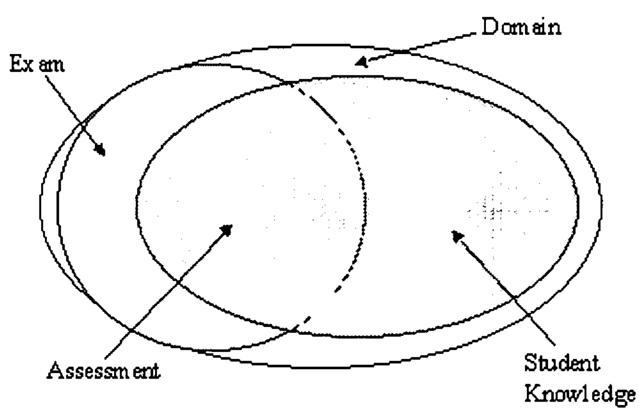
ABSTRACT

An alternative method of measuring the knowledge of students is to use mental models, and specifically concept maps. Concept maps provide a visual representation of conceptual and relationship knowledge within a particular domain. This study builds on previous studies and attempts to reduce their methodological weaknesses. Students in several undergraduate sections of an MIS Telecommunications course were asked to create concept maps of their Telecommunications knowledge at three distinct points throughout the semester. These concept maps were compared across all students at a single point in time, within students across the three time periods, and against the concept map of a domain "expert" at both the individual and composite levels. Findings indicate that the individual and composite maps increased significantly in size over time, and comparisons with the "expert" map show a significantly increasing overlap of concepts over time. Moreover, this study shows the applicability of this technique as an alternate assessment method.

INTRODUCTION

Information systems (IS) educators are tasked with preparing students with a broad education in business and IS, but measuring students' total knowledge can be difficult. Throughout a semester, students complete quizzes, tests, homework, and other assignments to demonstrate their mastery of the particular topic or domain of concern. When taken together, these measures of knowledge tell how much students know, and just as important, what they do not know. Still, most of these measures are very structured and limiting to the students—they may know 85% percent of the course's material, but the test, quiz, or homework assignment may only cover 50% of the material, including the 15% they did not know (see Figure 1). Moreover, these traditional techniques do not allow the students to demonstrate knowledge and mastery beyond the assessment technique. To increase knowledge measurement accuracy, these traditional assessment formats should be supplemented with alternative approaches.

FIGURE 1
TRADITIONAL ASSESSMENT



One alternative approach to knowledge assessment is the use of mental models, and specifically concept maps or concept webs. When a student creates a visual representation of his/her cognitive conceptualization of the IS field, viewers of that map get an inside look into that student's mind. The concepts and their relationships to each other are represented visually, showing the items that the student knows, their relationships, and the items that the student does not feel are important enough to be included.

The purpose of this research is to illustrate a potential use of concept maps as an assessment tool of students' conceptual knowledge of the IS domain (though applicable to other domains), and specifically Telecommunications. For the purposes of this research, Telecommunications (Telecomm) includes topics such as the Internet, networking, cabling, and communications, among others, and the regulations that govern them.

RESEARCH QUESTIONS

Previous studies involving concept maps and the field of information systems were limited in their findings (e.g., Freeman and Urbaczewski, 2001). This was mostly due to the methodology and a focus on concept maps drawn over a five-week period, and not as a snapshot within a short period of time. These studies did not utilize concept maps in a traditional assessment scenario, and, therefore, a clear insight into the usefulness and merits of concept maps has not been provided and there are a number of questions left to be answered regarding the use of concept maps as assessment techniques. This study attempts to answer the following research questions.

1. How does the knowledge of individual students change over time?

2. How does the composite knowledge of students change over time?

3. How does the knowledge of individual students compare to that of the "expert" over time?

4. How does the composite knowledge of students compare to that of the "expert" over time?

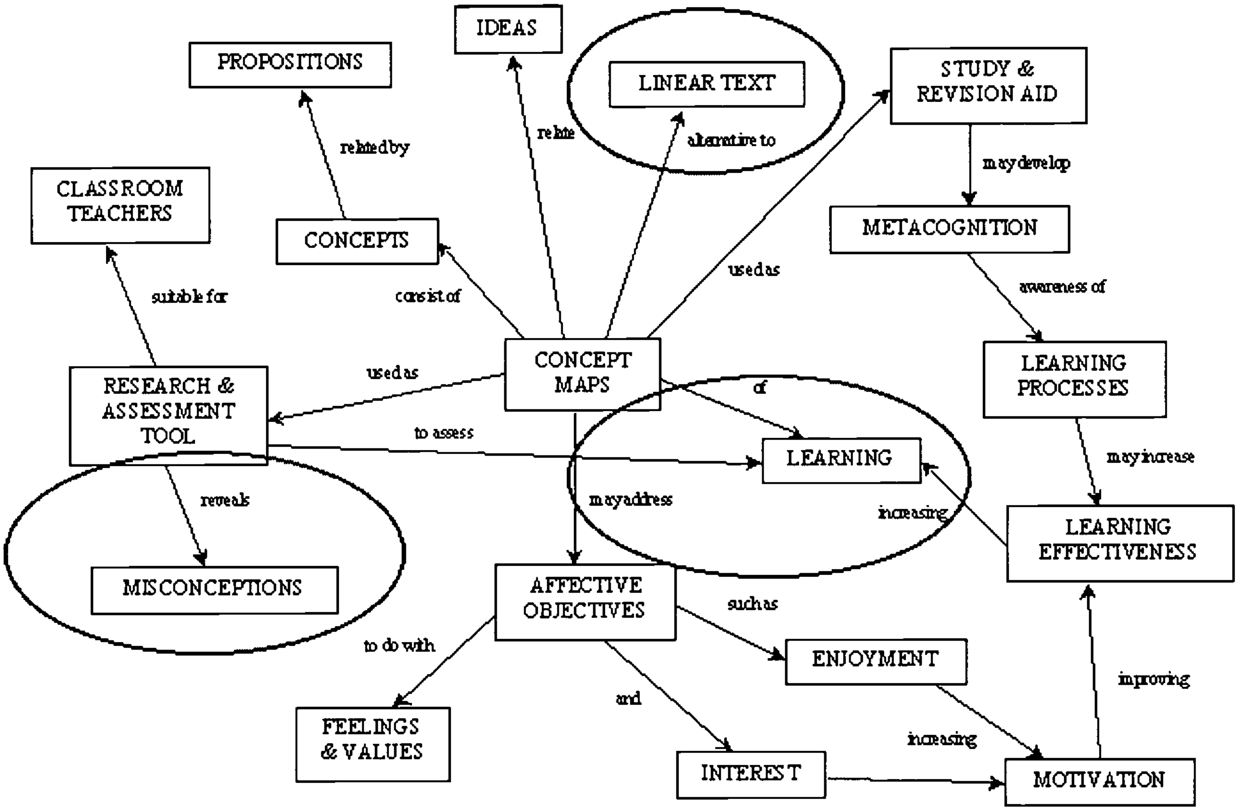
The analyses will provide insight into several issues. First, the concept maps will show what the students know (or at least feel to be important) regarding Telecommunications. Second, comparisons of the students' maps to an expert's map will provide information regarding how much is learned from the course and whether the concepts that are learned and included in the maps are done so "correctly" and as intended according to the expert – the faculty instructor. Third, comparisons of the three concept maps of individual students will provide a measure of how the student's knowledge of Telecommunications changes over time. Finally, if there are major differences between the student maps and the expert map, changes may be necessitated in the teaching of the Telecommunications class(es) so that the students have closer conceptualizations to the expert. These concept maps could potentially be used as an overall assessment of the department's teaching efficacy or simply as a view into the students' minds.

PRIOR LITERATURE

The use of mental models, specifically concept maps, can aide in the assessment of knowledge at a conceptual level (Fisher, 1990; Fisher et al., 1990; Gaines and Shaw, 1995; O'Neil and Klein, 1997). Concept maps provide a visual representation of conceptual and relationship knowledge of main concepts and major sub-topics within a particular domain (Hoover and Rabideau, 1995). Concept maps consist of nodes that represent the concepts and optionally labeled arcs that connect the nodes and represent the presence of a relationship. Concept maps look like a spider's web consisting of many concepts or nodes connected to each other by lines signifying the presence of relationships. Concept maps are typically assessed by comparing them to an expert's map in either quantitative or qualitative forms. Other assessment techniques include counting the number of concepts, the number of relationships, and the number of interconnections to determine the degree of complexity. See Figure 2 for a sample concept map.

Other forms of mental models such as cognitive maps, semantic networks, and schemata can also be used to represent relationships between concepts. However, they differ from concept maps in that they also include directionality to the relationship or causality between the concepts (Fisher, 1990). Concept maps were chosen as the assessment method because they do not require any temporal or cause/effect relationships between the concepts. In addition, concept maps support the notion of hierarchy, though they do not force a hierarchy.

FIGURE 2
SAMPLE CONCEPT MAP (TABER, 1994)



A general concept map showing the mapping of "concept maps" according to Taber. Note that the links are displayed as arrows showing the direction of the link (not causation), a convention not always used by others.

Concept maps have been used for many years as a means for communicating knowledge in fields such as education, biology, history, mathematics, engineering, computer science, and communications (Cliburn, 1986; Gaines and Shaw, 1995; Wallace and Mintzes, 1990; Williams, 1995). As seen in Figure 2, concept maps are an alternative to linear text, they help reveal misconceptions, and they increase learning. Freeman and Urbaczewski (1999) describe the use of concept maps as an "end-of-[academic] major" assessment technique to measure students' IS knowledge gained throughout their coursework. While there may be merit in creating and implementing some sort of assessment measure to be given to students after they complete all of their coursework, this would involve major cultural and pedagogical changes and is unlikely to happen at most institutions in the near term. Even so, this study was an initial attempt at using concept maps as an IS educational assessment technique. However, as described in Freeman and Urbaczewski (2001), there were a number of limitations and weaknesses associated with that first study.

First, there were no comparisons within individuals over time. Research suggests that concept maps indeed show the differences between novices and experts within a field (Markham et al., 1994; Wallace and Mintzes, 1990), so future studies should analyze the differences in concept maps from individuals drawn at different points in time. A second weakness was that the assignment covered a five-week period, as opposed to one or more snapshots in time. Concepts maps drawn over five weeks will likely be different from concept maps drawn within a time period of several hours, or shorter. Third, while the study focused on individual students and their individual concept maps, there was no control over the students to assure the researchers that there was no outside collaboration by the students during the five-week time period.

Finally, it should be noted that students have typically found concept maps to be fun (Freeman and Urbaczewski, 1999; Taber, 1994), an emotion unlikely to be expressed with regard to many other traditional assessment methods like exams and quizzes.

RESEARCH METHODOLOGY

This current study takes the composite knowledge of the above literature review and, with a focused effort based on the concept mapping literature from other disciplines, attempts to eliminate the weaknesses of this earlier work within IS.

Eighty-five students in an undergraduate MIS telecommunications course at a large U.S. university were the subjects for this study. At three different times throughout the Spring 2001 semester—during the first week of class, during the eighth week of class, and during the last week of class—a third party (not the instructor) visited the classes and witnessed the students as they created concept maps centered around Telecommunications. Prior to the first visit, the students were given a brief (15 minutes) introduction and training session on the subject of concept maps, how they can be drawn, and what they can show the reader. The students were given a blank sheet of paper to use in creating their concept maps, and they were given 20 minutes to create their maps. Students were not permitted to look at earlier maps in creating a current map, nor were they allowed to keep copies of the maps that they created.

As an incentive to participate, any student that completed all three concept maps during the semester received three bonus percentage points towards his/her overall course grade. Sixty-two students completed all three maps, and those sets of maps are the objects of analysis.

ANALYSIS

Analysis of the concept maps consisted of the following:

Coding Scheme

Each map was redrawn verbatim, but only focusing on and including the concepts and relationships regarding Telecomm. The cutoff for inclusion was to not include any concept and the associated relationships if that concept would not be included in a typical textbook chapter on telecommunications or internetworking. Therefore, "web-enabled database" would be included, but its relationship to "SQL" and "SQL" as a concept would be beyond the scope of Telecomm. Two outside coders, unaffiliated with the study, completed these redraws and the rest of the coding process to prevent any undue biases on the part of the authors from creeping into the analysis. Both authors independently compared the redraws for consistency and for concept categorization.

Following these redraws, the maps were randomly split into two groups. Using the maps from Group A, a set of consistent terms was developed to create a consistent coding scheme for all of the maps. In other words, if one map contained "employee" and another map contained "worker," or if one map contained "cabling" and another map contained "wiring," the coding scheme was necessary to select one term to be used in all instances of these synonyms to keep all of the maps consistent with each other. This coding scheme was then applied to Group B, and the maps from Group B were redrawn using the new coding scheme. Any concepts that were part of Group B, but not included in the coding scheme, were added to create a more robust scheme. The maps from Group A were then redrawn using this revised coding scheme. This process was repeated until all concepts from Groups A and B were accounted for in the coding scheme and all of the maps had been redrawn using the finalized coding scheme. Once the maps were redrawn with the finalized coding scheme, each concept and relationship from every map was entered into a software package for manipulation and analysis.

General Statistics

The final coding scheme contained 751 unique concepts, though there were over 1,600 total concepts (when including synonyms) used by the students. The 186 maps (62 students x 3 maps each) contained 5,000 total concepts in 2,606 unique relationship pairs, and over 5,100 total relationships. Across all maps from all rounds, there was a mean of 27 concepts and 28 relationships on each map. The smallest map had 7 concepts and the largest had 50. These same two maps also anchored the range of relationships with 6 relationships and 55 relationships, respectively. Of all 186 maps, only three had less than 10 concepts, and only 6 had less than 10 relationships.

Individual Maps

Prior research as well as everyday classroom experience indicates that the student concept maps should increase in size over time, representing greater domain knowledge. Fifty-seven (out of 62) students had larger maps in the second round than in the first round. Additionally, 49 students had larger maps in the third round than in the second round. For 48 students, their third round map was the largest of the three rounds, and for 44 students, each round's map was larger than the previous round. Overall, therefore, the maps of individual students did increase in size throughout the study.

Composite Maps

More details regarding the changes in the individual maps over time can be learned from analyses of the composite maps from each round. Table 1 presents descriptive statistics for each round.

TABLE 1
DESCRIPTIVE STATISTICS FOR COMPOSITE MAPS

	Round 1	Round 2	Round 3	p-value
Unique Concepts	380	418	459	n/a
Total Concepts	1175	1742	2083	n/a
Unique Relationships	841	1133	1271	n/a
Total Relationships	1196	1789	2147	n/a
Mean Concepts	18.95	28.10	33.60	<0.001
Mean Relationships	19.29	28.89	34.63	<0.001
Complexity	1.34	1.79	2.03	0.127

Overall, the maps were significantly larger in each subsequent round in terms of concepts and relationships. They also increased in complexity in each subsequent round (a measure of the number of relationships depicted in the map beyond the minimum necessary to connect all of the concepts linearly), though not at a significant level.

Based on the mean number of concepts and the mean number of relationships in each of the three rounds and overall, the following four tables (Table 2-Table 5) present the most common concepts and relationships for the respective rounds and overall. More concepts and relationships are included in all four tables in order to accurately represent the frequency distribution and not omit concepts or relationships with the same frequency. In other words, while Round 1 had a mean of 19 concepts, the top 22 concepts are shown in Table 2 to complete the frequency of all concepts appearing on 12 maps. Similar adjustments have been made to the concepts and relationships in Tables 2-5. These "amended means" will also be used below for comparisons to the expert's map.

The Expert's Map

In addition to the student maps, an independently-drawn concept map of an "expert"—the faculty member who taught these sections of Telecommunications—was collected for analysis and comparisons. The expert's map contained 86 concepts and 103 relationships, giving a complexity score of 18. For comparison, the largest student map contained 50 concepts and 55 relationships (also the maximum), and this map was in the third round. The maximum complexity score for any of the student maps was 10, but this was in the first round. Therefore, without any additional comparisons and analyses, it is already quite apparent that the expert's map is much larger and more complex than any map drawn by the students.

Even so, comparisons can be made with the individual maps against the expert's map, and with the composite maps and summary round data against the expert's map. Every student map had at least one concept in common with the expert's map, and some maps had up to 23 concepts in common. While these 23 concepts only represent 27% of the concepts on the expert's map, they represent 64% of the student's map. This indicates that while nearly every map was much smaller in size than the expert's map, some of the maps contained a substantial amount of overlap in terms of the concepts included.

Table 6 shows the number of concepts, on a composite level, contained in both the students' maps and the expert's map. The increasing overlap with the expert's map in each subsequent round was significant for all three measurements—actual number of overlapping

TABLE 2
ROUND 1 MOST COMMON CONCEPTS AND RELATIONSHIPS

Concept	# of Maps	Relationship	# of Maps
Telecommunications	63	Telephone:Telecommunications	23
Telephone	34	Telecommunications:Computers	18
Internet	33	Telecommunications:Networks	18
Computers	32	Telecommunications:Internet	17
Cellular	30	Telecommunications:Business	12
Networks	24	Telephone:Cellular	11
Email	22	Telecommunications:Communication	10
Business	21	Telecommunications:Fax	9
Cabling	21	Telecommunications:Technology	9
Individuals	16	Telecommunications:Individuals	9
LAN	16	Wireless:Telecommunications	9
Satellites	15	Telecommunications:Cellular	7
Wireless	15	Telecommunications:Information	7
Fax	13	Networks:LAN	7
Networking	13	WAN:Networks	7
Video Conferencing	13	Telecommunications:Satellites	7
WAN	13	Video Conferencing:Telecommunications	6
AT&T	12	Television:Telecommunications	6
Modem	12	Telecommunications:Cabling	6
Pagers	12	Internet:Computers	6
Speed	12	Telecommunications:Speed	6
Technology	12	Networks:Computers	6
		Telecommuting:Telecommunications	6

TABLE 3
ROUND 2 MOST COMMON CONCEPTS AND RELATIONSHIPS

Concept	# of Maps	Relationship	# of Maps
Telecommunications	63	Telephone:Telecommunications	22
Telephone	40	Wireless:Telecommunications	19
Wireless	35	Telecommunications:Networks	16
Fiber Optic	32	Transmission Media:Fiber Optic	13
LAN	32	Transmission Media:Telecommunications	13
Protocols	27	Telecommunications:Computers	12
WAN	27	Telecommunications:Networking	11
Internet	26	Telecommunications:Internet	11
TCP/IP	26	Telecommunications:Protocols	11
Transmission Media	26	TCP/IP:Protocols	11
Cellular	25	Networks:LAN	11
Star	25	Wireless:Cellular	11
Network Topology	24	Twisted Pair:Transmission Media	10
Networks	24	Telecommunications:LAN	10
Cabling	23	WAN:Networks	10
Twisted Pair	23	Star:Network Topology	10
Analog	20	Telecommunications:Network Topology	9
Data	20	Network Topology:Bus	9
Email	20	Telephone:LATA	8
Modem	20	Telecommuting:Telecommunications	8
Bus	19	Telecommunications:Data	8
Digital	19	Networking:LAN	7
Computers	18	Telecommunications:Data Sharing	7
Ring	18	Ring:Network Topology	7
LATA	16	Wireless:PDAs	7

Table 3
(continued)

Concept	# of Maps	Relationship	# of Maps
Microwave	16	WAN:Networking	6
Phone Companies	16	TCP/IP:Internet	6
Coaxial Cable	15	Telecommunications:Connections	6
Ethernet	15	WAN:Telecommunications	6
OSI Model Structure	15	Telecommunications:Technology	6
Voice	15	WWW:Internet	6
		Transmission Media:Cabling	6
		Telecommunications:Security	6
		Telecommunications:Communication	6
		Telecommunications:Switched Circuit Service	6
		Telecommunications:OSI Model Structure	6
		Telecommunications:Error Checking	6

TABLE 4
ROUND 3 MOST COMMON CONCEPTS AND RELATIONSHIPS

Concept	# of Maps	Relationship	# of Maps
Telecommunications	63	Wireless:Telecommunications	25
Wireless	51	Telecommunications:Internet	23
Telephone	44	Wireless:Cellular	22
Internet	43	Telephone:Telecommunications	19
Cellular	36	Transmission Media:Fiber Optic	17
LAN	36	Telecommunications:Networks	17
Fiber Optic	35	Telecommunications:Security	17
DSL	32	Security:Firewall	14
WAN	32	Twisted Pair:Transmission Media	14
Security	31	Transmission Media:Telecommunications	13
Bus	29	TCP/IP:Protocols	13
Twisted Pair	29	Telecommunications:LAN	12
Star	28	Star:Network Topology	12
Modem	27	Network Topology:Bus	12
Transmission Media	27	WAN:Telecommunications	11
Cabling	26	Wireless:PDAs	10
Network Topology	25	Telecommunications:Hardware	10
Networks	25	Networks:Network Topology	10
Email	24	Network Topology:Mesh	10
Ethernet	23	Networks:LAN	10
Ring	22	Ring:Network Topology	9
TCP/IP	21	Wireless:Satellites	9
Digital	20	Telephone:Switched Circuit Service	9
Mesh	20	WAN:Networks	9
Protocols	20	Telecommunications:Switched Circuit Service	8
Satellites	20	NICs:Hardware	8
Video Conferencing	20	Wireless:Bluetooth	8
Analog	19	Video Conferencing:Telecommunications	8
Firewall	19	Telecommunications:Network Topology	7
Hardware	19	Telecommunications:Data Sharing	7
Hubs	19	Telecommunications:Protocols	7
Router	17	Telecommunications:DSL	7
Microwave	16	Protocols:IPX/SPX	7
Coaxial Cable	15	Telecommunications:Cellular	7
MAN	15	Wireless:Microwave	7
Switched Circuit Service	15		

TABLE 5
OVERALL MOST COMMON CONCEPTS AND RELATIONSHIPS

Concept	# of Maps	Relationship	# of Maps
Telecommunications	189	Telephone:Telecommunications	64
Telephone	118	Wireless:Telecommunications	53
Internet	102	Telecommunications:Internet	51
Wireless	101	Telecommunications:Networks	51
Cellular	91	Wireless:Cellular	38
LAN	84	Telecommunications:Computers	36
Fiber Optic	76	Transmission Media:Fiber Optic	31
Networks	73	Networks:LAN	28
WAN	72	WAN:Networks	26
Cabling	70	TCP/IP:Protocols	26
Email	66	Transmission Media:Telecommunications	26
Computers	63	Telecommunications:LAN	25
Modem	59	Telecommunications:Security	24
Star	56	Twisted Pair:Transmission Media	24
Transmission Media	56	Star:Network Topology	22
Twisted Pair	55	Telecommunications:Communication	21
TCP/IP	53	Telephone:Cellular	21
DSL	51	Telecommunications:Business	21
Protocols	51	Network Topology:Bus	21
Bus	50	Telecommunications:Technology	20
Network Topology	50	Telecommunications:Networking	19
Security	47	Telecommuting:Telecommunications	19
Digital	46	Security:Firewall	19
Satellites	46	Telecommunications:Protocols	19
Video Conferencing	46	Video Conferencing:Telecommunications	18
Business	43	Telecommunications:Cellular	18
Analog	42	WAN:Telecommunications	18
Ethernet	42	Wireless:PDAs	18
Ring	42		

TABLE 6
OVERLAP BETWEEN INDIVIDUAL AND EXPERT MAPS

	Round 1	Round 2	Round 3	p-value
Mean Overlap Concepts	4.68	10.76	12.87	<0.001
Percent of Students' Maps	24.39%	37.76%	38.25%	<0.001
Percent of Expert's Map	5.44%	12.51%	14.97%	<0.001

concepts, percentage of the students' maps that overlap with the expert's map, and percentage of the expert's map contained in the students' maps.

There are two additional ways to compare the expert's map with the composite maps from each of the three rounds. The first is by comparing the most common concepts from each round to the concepts used by the expert. In Round 1, out of the 22 ("amended mean") most common concepts, only 6 (27.27%) were also a part of the expert's map. For Round 2, this number jumps to 21 out of 31 (67.74%). However, the number falls to 22 out of 36 (61.11%) for Round 3. Still, this does indicate a fair amount of overlap between the composite maps from each round and the expert's map. The second comparison is determining the number of concepts used by the expert that appear in any of the students' maps in a given round. Of the 86 concepts in the expert's map, 38 did not appear on any students' map in Round 1, 22 did not appear on any students' map in Round 2, 14 did not appear on any students' map in Round 3, and 6 never appeared on any students' map in any of the rounds, again indicating an overall overlap between the students' maps and the expert's map, especially in the later rounds.

Course Grades

The final analysis is the correlation between the students' final course grades (based on traditional assessments) and their concept maps from Round 3. The course grades were converted to a GPA based on a 4.0 being an A. Table 7 shows these correlations.

TABLE 7
CORRELATIONS OF CONCEPT MAPS WITH COURSE GPA

	GPA	p-value
Concepts	0.376	0.003
Relationships	0.370	0.003
Complexity	0.044	0.732

The positive and significant correlations between GPA and both Concepts and Relationships indicate that the students who performed well in the traditional assessments also produced concept maps that were larger with more relationships. While the correlation with GPA and Complexity was slightly positive, it was not significant as expected based on the relatively low complexity of the concept maps.

DISCUSSION

The results are fairly clear: as the students progressed throughout the semester, their concept maps significantly increased both in size and in similarity to the expert's map. We would expect any other assessment method to yield similar results, hopefully as a measure of learning.

One might wonder if the increasing number of concepts and relationships would be a self-fulfilling prophecy. That is to say, that certainly by the end of the semester, the students would have been exposed to more material and would have been able to express more of it on their maps. This is probably true to some extent. Of importance to us, additionally, is their ability to continue to recall basic topics that were primarily discussed in the beginning of the semester, as well as relate those topics to their understanding of Telecommunications before beginning the course. This demonstrates additive knowledge on the reshaping of prior knowledge.

If we look at the relationship between the average overlap of concepts, even at its highest (12.87 concepts: 38.25% of the students' maps, 14.97% of the expert's map), we may conclude that the transfer of knowledge is limited and that both the professor and students should be given failing grades. Is this so? We do not believe it is. We believe that this is rather a celebration of the educational system and the abilities of individuals to focus in areas that may not be of primary interest to the expert. This is the ability to inspire. Of course there must be some base level of knowledge in order for one to inspire, and we at least find that in the increasing number of concepts represented in the students' maps. But to suggest that the goal is to have the students repeating the course material as a mantra upon completion would imply that our universities are no more than memorization camps. These maps are one more tool in getting inside the minds of our students and observing the relative importance of certain concepts.

In the results, we find that course grade is positively and significantly correlated with both number of concepts and number of relationships in the individual maps. This can be attributable to a number of factors. First of all, and what we as educators are more likely to espouse, it is a demonstration of understanding of the subject matter. While it is true that the individual who does not know anything about the subject could not draw a concept map similar to an expert's map, the opposite relationship is not necessarily true. We also cannot say for sure that the primary cause of the correlation is increased knowledge. Other mitigating factors, such as motivation, attitude towards course, attitude towards instructor, or attitude towards the researcher could all play a role in identifying the reasoning behind the correlation. For the purposes of this paper, we make no claim beyond the existence of positive and significant correlations. Future research should attempt to measure these differences.

We find no relationship between grade in course and complexity. This is likely related to the low overall complexity of all student maps. Future research should also investigate the reasoning behind relatively low complexity and the mental model of the student. For example, does the student view knowledge as largely hierarchical, or as an interconnected web of concepts, and how does the student demonstrate that knowledge?

These concept maps allow the instructor to "check" on what students understand and know regarding the course and his/her expectations. Of course, quizzes and exams attempt to do just that, but they are limited in what can be conveyed and in what can be covered. Additionally, beyond the quantitative analyses that appear in this paper, there are several valuable qualitative analyses that can be performed on the concept maps. By looking for "strange" relationships within the concept maps, the instructor can clearly see what the students don't understand, or at least misunderstood at one point. For example, if the relationships "Network Topology:LAN" and "Network Topology:Client Server" appeared, it would be apparent that there is a misunderstanding of Network Topology within the class. These "strange" relationships are particularly helpful when uncovered in the middle of the course. In the beginning of the course, many students will likely have misunderstandings about concepts and relationships merely due to the fact that they have not yet been covered adequately, if at all. At the end of the course, the instructor may not have the time to properly correct the misunderstandings before the students take part in traditional, graded examinations. However, in the middle of the course, the instructor has not only covered a fair amount of the material, but also has the necessary time to clarify misunderstandings.

A second qualitative analysis involves the actual knowledge and understanding conveyed in the concept maps. Ideally, as the course progresses, the concept maps will contain concepts and relationships that indicate a deeper understanding of the material. These concepts and relationships will go beyond the basic terminology of the course, and the relationships will become more complex. These qualitative analyses go beyond traditional assessment techniques in providing the instructor with a much clearer view of what his/her students know, think, and understand.

A potential limitation with interpreting the data is that the researchers and coders were required to take the topics as they were printed on the paper. It is difficult from the writing to ask "is that what he/she really meant?" From the context and the relationships, it is easy to tell that in one sense "cable" may refer to a type of Internet access through a cable TV company, while in another sense "cable" may refer to a length of copper surrounded by insulation. However, this interpretation is certainly not perfect. The alternative, though, would be to have students pick words and definitions from an approved list. This would certainly defeat the purpose of this free association task and almost "force" the results.

CONCLUSION

This study is an attempt to better assess students' knowledge using concept maps, and an attempt to modify previous studies and eliminate their weaknesses. Several issues should be noted: the contributions of this study and the need for additional research. First, this study makes several contributions to research and to teaching. It informs the field of IS academics in general, and specifically Telecomm academics, of an additional method for the assessment of students that has gained support in other academic fields such as education and psychology. Granted, this method may not be appropriate to replace other assessment methods, but that will depend on the specific situation and the type of knowledge to be assessed. This empirical study also demonstrates the applicability of this assessment method in a real classroom situation and shows what can be learned.

While the concept maps of these students were compared to an expert, this expert was a single faculty member and not all of the faculty members that teach or have taught the Telecommunications class at this particular institution. Student maps could be compared to a "departmental" or "institutional" map or even to the map at a discipline level from the IS 1997 or IS 2002 requirements (available through the AIS website, http://aisnet.org/Curriculum/). Future research should also analyze concept maps created by groups as an alternative method for conveying knowledge. Another area for future research is the use of concept maps in other ways within the classroom, such as for organizing lectures and units, for brainstorming, or for bringing together diverse viewpoints.

The optimal means for assessing student knowledge may often seem like the quest for the Holy Grail. While concept mapping may not be the "silver bullet" that is all-encompassing and useful in every situation, it is one more "fly" in the teacher's "tackle box," and one that should not be ignored. This study attempts to show the usefulness of this tool in one situation, and its applicability to many other situations can be surmised from this study.

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