Analysis of Student Preconceptions Related to Quality of Service and Basic Principles in Telecommunications

Abstract

Student preconceptions play an important role in education. In the constructivist theory, the students' cognitive process is understood as building new knowledge using existing ideas as a starting point. However, students' preconceptions and intuitions are often false, naïve or incomplete. When aware of this fact, instructors can find these misconceptions early in a course, and devise an educational methodology to address them[19, 2].

We aim to identify student preconceptions related to networking and telecommunications engineering technology with the objective of increasing the effectiveness of our teaching methodologies. We hypothesize that to effectively address misconceptions, student culture must be taken into account. In addition, by analyzing student responses to misconception testing, we have taken the first steps in developing a concept inventory for telecommunications and networking.

This work augments a previous study on STEM undergraduate students' preconceptions regarding Quality of Service (QoS) in telecommunications[13], by giving the same survey to a larger number of students across different programs and countries and investigating the effects of culture and experience on preconceptions related specifically to QoS.

In this study, the survey was given to two new groups of students and the pre- and post-instruction responses were the analyzed. The first group was primarily from India and were studying towards a graduate degree in telecommunications; the second group was primarily from the USA and were taking a networking class as part of their undergraduate degree. The students were asked to respond either "yes" or "no" to multiple questions and then explain the reasoning behind their response. The data from each group was analyzed, the undergraduate data was then compared with data from the previous study, and the undergraduate and graduate data were compared to each other with respect to culture and experience [20].

In addition, a new survey was given to another set of graduate students to study preconceptions related to concepts in telecommunications that were not related to QoS. We used our overall results and analyzed the wording, key phrases and key words in their explanations, to create an initial concept inventory specific to telecommunications.

This concept inventory will allow instructors to prepare their instructional material and tune their didactic approaches to meet specific student need - some of which may be related to culture and experience.

Introduction

The context of this work is an engineering technology program that offers telecommunications and networking courses at both the undergraduate and graduate level. The vast majority of undergraduate students are American, whereas the graduate students are largely from India. Over the years, the authors have observed (anecdotally) that each of the two groups of students face different difficulties in learning the material, and that instructional methods that are effective with one group are not necessarily effective with the other. Seeing this as an opportunity to improve our teaching and the educational achievement of all our students, we developed an initial research plan with the following hypothesis:

- Given our specific instructional methods, the difference in the learning processes of the two groups of students is due, at least in part, to their different national origins, educational experience, expectations, outlook, etc. (loosely referred to as “culture”), and not only due to their age or other differences.
- We should use the theory of preconceptions in education to obtain an initial understanding into how our students think about the subjects we teach them – both before and after instruction.
- If our students in fact have wrong preconceptions and our current instructional approach does not correct them, then we should develop a telecommunications concept inventory (which does not exist today) to help us identify as many existing preconceptions as possible, and to gradually measure, revise and improve our teaching.

We report our initial results in this paper. We quantified the learning achievements of both groups of students using pre- and post-instruction tests. We ran a statistical analysis of the test results and we identified that, with high probability, the two groups learn some telecommunications concepts in different ways. Using the same tests, we identify likely student misconceptions in the areas of communication systems bandwidth, network resource reservation and its implications on quality of service (QoS), and network utilization versus efficiency.

The notion that students from different cultures learn in different ways has some support in the literature [16,14,8]. Geert Hofstede defines culture as “the collective programming of the mind that distinguishes the members of one group or category from others” [20]. House offers a different definition of culture: Culture can be conceptualized as “shared motives, values, beliefs, identities, and interpretations or meanings of significant events that result from common experiences of members of collectives that are transmitted across generations” [12].

Wursten and Jacobs present five cultural dimensions which influence the learning process to define learning environments in which students feel comfortable as well as their expectations of teachers. These are: Power Distance Index (PDI), Individualism vs. collectivism (IDV), Masculinity vs. femininity (MAS), Uncertainty Avoidance Index (UAI), and Long Term Orientation (LTO). These indices help define learning environments which foster positive knowledge transfer or learning based on culture and lead to an understanding of “majority preferences”. These preferences influence communication protocols between students and teachers, how well students work in groups and how teachers address certain groups (ethnic or otherwise), grading/ranking scales, success and failure assessment, structured vs unstructured learning/teaching, and variability in “correct” or accepted answers to questions or problems [20].

Gay states that, “[…] the academic achievement of ethnically diverse students will improve when they are taught through their own cultural and experiential filters” [7]. In our case, the ethnic diversity exists between instructor and students. We, as instructors, cannot change our backgrounds, but we believe it is possible to adjust our instruction to identify misconceptions and help students in their learning process, despite the potential mismatch in our “cultural and experiential filters”.

Given this background, we believe it is reasonable to hypothesize that our culture affects how we learn (and how we teach). Our culture affects how we think about the world and form concepts, correct or otherwise. It is these ideas that this study aims to unpack with regard to basic telecommunications principles and networking.

The study of preconceptions (often referred to as “misconceptions”) is a widespread and very useful tool to gain insight into the cognitive process. Preconceptions influence our understanding and have a direct effect on how we process information to learn, solve problems and arrive at conclusions [3]. Clement’s work with students in introductory mechanics courses discusses “conceptual primitives” which manifest themselves in “stable, alternate views of force and acceleration” [4]. Clement’s studies pair force and acceleration as concepts that interplay in students “understanding of motion related to objects.”

On a deeper level, diSessa identifies “phenomenological primitives”, or p-prims, which are knowledge structures abstracted from experience [5, 17]. In a sense, p-prims relate to “intuitive knowledge”. P-prims are subjacent in the sense that students do not question, or think much about, them. However, experience shows that a major element of cognitive change in students occurs as they become aware of their own knowledge structures, and correlate them (often negatively) with actual phenomena. We believe that it is important to realize, as instructors, that what we may conceive as an atomic “concept” is in fact a set of ideas, known as a “coordination class”, which are influenced by p-prims. Effective change of a wrong misconception, then, may involve addressing a number of underlying p-prims. As a specific example from the field of networking, a concept such as Resource Reservation Protocol (RSVP) probably relies on coordination classes, such as network resources (fixed or shared), reservation messaging, and admission control.

However, it is easy to have a too simplistic view of preconceptions, where students are assumed to have “wrong knowledge” at the start of a course, and the instructor’s job is to turn it into “correct knowledge”, thus turning students into experts. It is more productive to think of preconceptions as a starting point in the students' continuous transition from novices to experts. In this sense, preconceptions are not mistakes to be replaced, but knowledge to be reconstructed iteratively [19].

This brings us to Concept Inventories (CI), a widely accepted instrument that helps instructors become aware of student preconceptions and assess to what degree these have been addressed by instruction. To quote the originators of the CI, "[…] effective instruction requires technical knowledge about how students think and learn" [11]. A properly designed CI can provide instructors with useful insight into the preparation of materials, assignments and learning experiences that incorporate knowledge about the students' state of mind.

A CI typically takes the form of a multiple-choice assessment, whose design has been guided by education research [1]. Its questions are tailored to identify students' implicit assumptions in a specific field and may be applied both pre- and post-instruction. There is no currently existing CI for networking and telecommunications. Our initial results seem to suggest that the development of a CI for this field would be very useful. However, we would like this CI to be applicable to a diverse set of students, with respect to both their culture and their educational level (undergraduate and graduate). At the moment, the development of such a CI is still in an early stage.

In summary, this study expands the breadth of knowledge on student preconceptions in STEM by including the subject of QoS in telecommunications, identifying some of the preconception(s), statistically analyzing the effects of these preconceptions and offering instructional insights than can ameliorate or eliminate negative effects on student learning related to these concepts.

Telecommunications Concepts

An important topic in telecommunications and network engineering is the study of network performance metrics and the factors that affect them. We present below a brief list of the telecommunications concepts related to our analysis. These concepts are taught (in slightly different form) in one undergraduate course and two graduate courses.

Bandwidth has two different meanings in networking. One is colloquially equivalent to data rate, measured in bits per second (bps), of a network link. For example, a gigabit Ethernet link can potentially transmit up to 1×10^{-9} bps. The second, historically more accurate meaning of the term is a measure the width of the link's frequency band that is available for use, and it is measured in hertz. The two concepts are related, in the sense that increasing a link's data rate (or, more accurately, its baud rate) requires a larger frequency band [6].

Bandwidth plays a role in many aspects of a network. One example is transmission of an inherently analog source (e.g. audio). A higher-quality audio signal will require a larger bandwidth (in any of the two uses of the term), because a higher-quality analog-to-digital conversion produces more data. Another example is signaling. As the complexity of the network's services increases, so does the signaling, requiring a corresponding increase in the network's bandwidth.

Quality of Service. A telecommunications network, in general, cannot offer perfect service to all users. Phenomena such as congestion, data loss, and network downtime are perceived by users as service degradations, examples of which are increased latency, reduced throughput or loss of data. However, users may be willing to accept increased cost in exchange for the network giving higher priority to their data. This is quantified in contracts called service-level agreements (SLA) which specify the particulars of the quality of service offered as well as cost and penalties if the quality metrics are not met. QoS is an industry-wide set of standards and techniques for designing networks capable of giving preferential treatment to specific categories of data. Although any network operator may employ QoS techniques, they are more relevant for large networks with many users and services. Currently, it is assumed that commercial, enterprise and carrier-grade networks must offer SLAs, while small local or home networks do not usually do not (Microsoft TechNet 2003). An important QoS technique is the *Resource Reservation Protocol* (RSVP), which is used to pre-allocate network resources when a connection is created, in order to meet any existing SLAs [21].

Two important network analysis metrics are *network utilization* and *network efficiency*. Network utilization is the ratio between actual traffic and maximum theoretical traffic. Network efficiency is the ratio of the actual time it takes for a packet to reach the receiver and the theoretical minimum latency over a link [18]. These two concepts vary over time and are related - as utilization goes up (linearly), efficiency typically goes down exponentially [10].

One implication of QoS is that a network can be seen as a diverse set of interconnected nodes and requires control and configuration mechanisms to coordinate the operation of its parts. Traditionally, networks have had distributed control: no single node has knowledge or control over the entire network. Recently, a technique known as software-defined networking proposes that higher efficiencies require centralized control. The jury is still out on this question.

Methodology

Our student population is divided into two national groups – students from India and students from the United States of America. This allowed us to make initial conclusions based on culture with respect to preconceptions and learning.

An initial study involved a group of 24 undergraduate students [13]. This second survey had 36 undergraduate students enrolled in a networking technologies course as part of their telecommunications engineering technology option, and two sections of a graduate networking course with a total of 50 students. Prior to instruction, each student was asked three basic questions to gauge their understanding of the telecommunications concepts described above. The same questions were posted again after instruction. Each question requires the student to give a specific “True”/”False” answer, followed by an explanation of their reasoning.

All responses were analyzed and compared, creating paired response data. Individual question scores, average scores and normalized gain values were generated for each student’s performance for each question and overall score. We examined students’ explanations to identify words, phrases or ideas that may be particular to culture.

The two-part question was designed to inform the instructor if a student guesses or has a misunderstanding by identifying “disordered pairs”. An incorrect “yes” or “no” response paired with a correct explanation indicates a lack of understanding or a “misunderstanding”. This disordered pair is defined as “Scenario 1”. A correct “Yes” or “No” response paired with an incorrect explanation, indicates the student guessed. This is identified as “Scenario 2”. Incorrect “yes” or “no’ responses with incorrect “why” responses indicates “no understanding” as is identified as “Scenario 3”. Instances of misunderstanding, guessing and no understanding are identified. Each part of the question is assigned a metric or maximum point total. The scores for each part are summed and represent the total score for that question. Each question had a total of 5 points, resulting in a total of 15 points for all three questions. For each of the pre- and post-instruction surveys, the following data is collected:

- Individual question scores for each student – Parts A and B individually
- Individual question scores for each student – Sum of parts A and B
- Average student score for each question – Parts A and B individually
- Average student score for each question – Sum of parts A and B
- Total student score for all questions
- Average total student score for all questions
- Normalized Gain for each question (Parts A and B together). Normalized Gain is the difference in the POST vs PRE score divided by the class average for that particular question.
- The difference in PRE vs POST instruction disordered pair instances – Scenario 1
- The difference in PRE vs POST instruction disordered pair instances – Scenario 2
- The difference in the number of PRE vs POST instances – Scenario 3
- Two-tailed, paired sample tests were performed on student scores for all questions and TOTAL score.

The questions used in the pre-instruction and post-instruction surveys for the undergraduate and graduate networking students were the same and are shown below:

Question 1 (Pair 1) - Answer YES or NO

Part A - Increasing bandwidth leads to increased QoS. (1 Point)
Part B - Why do you think this is so? (4 Points)

Question 2 (Pair 2) - Answer YES or NO

Part A - Reserving bandwidth leads to increased QoS for all users. (1 point)
Part B - Why do you think this is so? (4 Points)

Question 3 (Pair 3) - Answer YES or NO

Part A - Increased utilization indicates a more efficient system. (1 Point)
Part B - Why do you think this is so? (4 Points)

In the case of our freshmen graduate students, we asked them the following four questions, in pre- and post-instruction. Each question has a multiple-choice selection; in addition, students were asked to explain why they chose as they did.

Question 1: If a network uses out-of-band signaling as opposed to in-band signaling, does it require (a) more, (b) less, or (c) the same bandwidth? Why?

Question 2: Compared to analog communications, digital transmission of an analog signal requires (a) more, (b) less, or (c) the same bandwidth? Why?

Question 3: The solution to networking challenges such as congestion require centralized control. (a) True or (b) False. Why?

Question 4: A link with a fixed data rate can be used to link transmitters and receivers operating at different data rates. (a) True or (b) False. Why?

Results and Statistical Analysis

In this section, we present the statistical results obtained in three different courses: an advanced undergraduate course, a first-semester graduate course and a second-semester graduate course. We will present a discussion of the results in the following section.

<u>Undergraduate course.</u> In this course, the sample size was 36 students. Pre- and post-test results are presented in Table 1. The *mean* column represents the mean knowledge gain for the sampled students, with corresponding standard deviation. The columns labeled *t* and *Sig. (2-tailed)* represent a two-tailed, paired-samples t-test on the mean knowledge. We consider the mean gain in student knowledge to be significant if the t-test results in a *p*-value of 0.05 or less. Otherwise, we consider that there is no demonstrable gain in student knowledge.

Table 1. Statistical results for pre- and post-testing in an advanced undergraduate course on networking and telecommunications.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	Q1_Post - Q1_Pre	.50000	2.40535	.40089	-.31385	1.31385	1.247	35	.221
Pair 2	Q2_Post - Q2_Pre	.75000	2.10272	.35045	.03854	1.46146	2.140	35	.039
Pair 3	Q3_Post - Q3_Pre	1.58333	2.68727	.44788	.67409	2.49258	3.535	35	.001
Pair 4	T_Post - T_Pre	2.83333	4.00892	.66815	1.47691	4.18976	4.241	35	.000

For question #1, on the relationship between an increase in bandwidth and an increase in QoS, the mean knowledge gain for the thirty-six (N=36) students was 0.500 with a standard deviation of 2.405. A two-tailed paired samples t-test on the mean knowledge for this question was not statistically significant ($t_{(35)} = 1.247$, $p = 0.221$). Thus, on average, students' knowledge associated with *bandwidth concepts* did not improve significantly over the duration of the semester.

For question #2, related to the relationship between resource reservation and QoS, the mean knowledge gain was 0.750, with a standard deviation of 2.103. A two-tailed paired samples t-test on the mean knowledge for this question was statistically significant ($t_{(35)} = 2.140$, $p < 0.05$). Thus, on average, students' knowledge associated with *resource reservations* improved significantly over the duration of the semester.

For question #3, the mean knowledge gain was 1.583, with a standard deviation of 2.687. A two-tailed paired samples t-test on the mean knowledge for this question was statistically significant ($t_{(35)} = 3.535$, $p < 0.05$) and we can say that, on average, students' knowledge associated with *network utilization* improved significantly over the duration of the semester.

1st-semester graduate course. A pre- and post-test study of graduate freshmen students was also performed. This course covers fundamentals of networking, without focusing on any specific standards, protocols or technologies. The sample size is 18 students, and the statistical analysis is presented in Table 2.

Table 2. Statistical results for pre- and post-testing in a graduate freshman course on networking fundamentals.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Q1_Post - Q1_Pre	1.00000	2.49706	.58856	-.24176	2.24176	1.699	17	.108
Pair 2	Q2_Post - Q2_Pre	-.22222	1.16597	.27482	-.80204	.35760	-.809	17	.430
Pair 3	Q3_Post - Q3_Pre	.55556	2.45482	.57861	-.66520	1.77631	.960	17	.350
Pair 4	Q4_Post - Q4_Pre	-.44444	1.75641	.41399	-1.31789	.42900	-1.074	17	.298
Pair 5	T_Post - T_Pre	.88889	4.01305	.94589	-1.10675	2.88453	.940	17	.361

Questions 1 and 2 are related to bandwidth; questions 3 and 4 are related to fundamental network design issues that affect quality of service in larger networks.

For this course, there is no significant gain in either of the studied knowledge areas. It is interesting to note, however, that many of the students in the sample can solve homework and exam problems related to these subjects. This contradiction suggests that there further research is needed to fully grasp the students' cognitive process.

<u>2nd-semester graduate course</u>. In this course, the sample size was 50 students. Results are presented in Table 3.

For question #1, the mean knowledge gain for the fifty (N=50) students was 0.100 with a standard deviation of 2.102. A two-tailed paired samples t-test on the mean knowledge for this question was not statistically significant ($t_{(49)} = 0.336$, $p = 0.738$). Thus, on average, students' knowledge associated with *bandwidth concepts* did not improve significantly over the duration of the semester.

Table 3. Statistical results for pre- and post-testing in a second-semester graduate course on networking concepts.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Q1_Post - Q1_Pre	.10000	2.10199	.29727	-.49738	.69738	.336	49	.738
Pair 2	Q2_Post - Q2_Pre	.28000	3.09733	.43803	-.60025	1.16025	.639	49	.526
Pair 3	Q3_Post - Q3_Pre	.82000	2.22866	.31518	.18662	1.45338	2.602	49	.012
Pair 4	T_Post - T_Pre	1.38000	4.09026	.57845	.21756	2.54244	2.386	49	.021

For question #2, the mean knowledge gain for the fifty (N=50) students was 0.280, with a standard deviation of 3.097. A two-tailed paired samples t-test on the mean knowledge for this question was not statistically significant ($t_{(49)} = 0.639$, $p < 0.05$), implying that on average, students' knowledge associated with *resource reservation* did not improve significantly over the duration of the semester.

For question #3, the mean knowledge gain for the fifty (N=50) students was 0.820, with a standard deviation of 2.229. A two-tailed paired samples t-test on the mean knowledge for this question was statistically significant ($t_{(49)} = 2.602$, $p < 0.05$). Thus, on average, students' knowledge associated with *network utilization* improved significantly over the duration of the semester.

Discussion

In an effort to measure the effectiveness of our instruction and to assess student preconceptions, we have undertaken pre- and post-testing of three different groups of engineering technology and telecommunications engineering technology students at the undergraduate and graduate levels. The results we have obtained were somewhat unexpected as, in some cases, created more questions than were answered.

We found that for some concepts none of the groups made any statistically significant progress, while for others undergraduate students made significant progress while the graduate students did not. As the courses had the same instructors, teaching methodology, material and other common factors, we believe that one key reason for the different levels of progress is that the undergraduate students were primarily from the United States while the graduate students were primarily from India. This seems to imply that our instruction methodology might be better suited to students of one culture than the other.

Our results indicate that all the students' knowledge of the basic performance metrics (utilization and efficiency) showed a statistically significant increase over the course of the semester. However, neither the undergraduate nor graduate students' knowledge with respect to bandwidth, whether related to QoS or to network traffic, showed any improvement.

The most surprising results was with regard to resource reservation and the relationship between network parameters (such as bandwidth) and QoS. Here, the undergraduate students' knowledge improved significantly over the course of the semester, while the graduate students' knowledge did not. We also saw that with respect to resource reservation, the undergraduate students had a positive normalized knowledge gain compared to the graduate students who had a negative normalized gain. We hypothesize that culture may be a significant factor in understanding this concept as the undergraduates are American students while the vast majority of graduate students are from India.

Moreover, the data suggests that graduate students' understanding of QoS concepts actually decreased during the semester. This may be related to the strength of their preconceptions regarding these concepts. The number of undergraduate students with incorrect knowledge in the area of resource reservation decreased from 21 to 9, while the number of graduate students in the same situation increased from 18 to 21 in the 2nd-semester course.

We present more detailed observations regarding bandwidth, reservation and QoS for each course below.

Undergraduate course. Thirty-two of the thirty-six, or 89% of undergraduate students responded that "resource reservation is user specific" and will benefit "those to which it is applied". This is in stark contrast to how the graduate students understand resource reservation.

This suggests that the two cultures involved in this study clearly, though initially, view resource reservation in very different contexts.

With regard to Question 1 (Pair 1), both groups students' knowledge associated with the concept of bandwidth did not improve significantly over the duration of the semester (Tables1 and 3). This may be attributed to the multi-faceted nature of the concepts inherent in this question. Students surveyed believed that increasing bandwidth "improves network performance", which is perceived as "reduced latency and response times". However, bandwidth is only one element in a robust network. Students need to understand that the capacity of a network is related not only to the bandwidth of transmission lines but also to the processing speeds of the switches, routers, servers, and memory in these devices. Students who don't consider nor understand these factors will mistakenly think that simply increasing bandwidth will improve QoS. These other elements related to network capacity need to be stressed and presented with their interdependencies related to QoS.

The instruction was effective in making clear that in an IP network, where traffic load is not deterministic and predictable, network congestion increases exponentially as utilization reaches 70% and thereafter. Network congestion results in decreased QoS levels. In fact, a network operator or service provider will attempt to maintain utilization at approximately 50% or less. Traffic shaping is a technique used to "smooth out" utilization, reducing spikes in utilization numbers for long periods of time. These concepts were stressed in the instruction phase and this effort resulted in a positive effect on student learning during the semester and dramatic increase in the number of 1/4 POST scores for this question – Question 3, Pair 3

1st-semester graduate course. In this course, many students failed to realize that the analog-to-digital conversion process increases a network's bandwidth requirements compared to analog communications systems; also, they failed to correlate the sophistication of a signaling scheme with its bandwidth requirements. In the students' explanations for their answers, we can identify key misconceptions. Some examples are:

- Creation of secondary control channels does not increase the traffic over a network.
- Digital pulses have small amplitude, thus small bandwidth requirements.
- Analog-to-digital conversion eliminates noise, thus reducing its bandwidth.
- The analog-to-digital conversion process does not result in increased bandwidth.

The results for question 3, related to de-centralized network control, and question 4, on handling varying data rates, are also striking. Despite ample evidence to the contrary, students fail to be convinced that de-centralized algorithms can be used in the operation of a network; they believe that only central control is feasible. Likewise, they don't contemplate the possibility of a network responding to traffic variations by using buffers, bit stuffing or flow-control mechanisms. Examples of misconceived explanations are:

- Only a central controller can detect when a problem occurs in the network.
- Only a central controller can fix packets that were received in error.
- Only a central controller can figure out the routing tables.
- If a node increases its traffic, other nodes will not be able to cope.
- If each node operates according to its own time reference, unavoidable problems will occur.
- This problem cannot occur, since all nominally equal clocks are in fact equal.

These concepts suggest to the authors that these students exhibit High PD, IDV and UAI indices[2].

<u>2nd-semester graduate course</u>. Thirty of the fifty, or 60% of graduate students responded resource reservation benefits all users for one or more of the following reasons:

- "It (RSVP) can be applied to specific users but NOT negatively affect others"
- "(RSVP) will give each user what they need and should not be reserved"
- "(RSVP) does not affect any single user"
- "(RSVP) places bandwidth in a bank for use"
- "RSVP means increased bandwidth"

It seems that these students feel that reserving resources will not deplete the resource pool but will improve QoS for users without affecting others in any way. This is in direct conflict with the undergraduate students' notion of resource reservation, who clearly understand that resource reservation has implications for users and services not identified to receive priority allocation of system resources. Not only are these conceptions in stark contrast, but their cultures are as well. It is this initial evidence that motivates the authors to continue this work and find correlations and causations for their hypothesis.

Conclusions and Future work

Culture may be a significant factor with regard to concepts particular to telecommunications and networking. In our student pool, we see stark contrasts in the way the students from India understand resource reservation as compared to the undergraduates which are the US. Another interesting finding is that the Indian students feel that central control is the best way to manage a network. As stated earlier, this indicates high PD, IDV and UAI indices [20]. The authors will seek to validate these initial claims by increasing the number of graduate and undergraduate telecommunications students surveyed to increase our data sets allowing more robust comparisons to validate and/or modify our survey instrument and validate our data analysis and findings. The researchers expect to increase the sample size to over 200, providing a more robust data set. In addition to the numeric data, a catalog of key words used in students' PRE and POST responses will be compiled and analyzed for key word correlation to instances of misunderstanding, guessing and no knowledge of the paired concepts. An initial set of keywords for resource reservation are listed in the discussion section above and are in quotes. Other misconceptions are listed in bulleted format and represent the misconceptions expressed by the 1st-year graduate students. The authors will extract specific words and phrases from these responses and seek to correlate these key words to the culture and native language of the students. These key words and phrases will be analyzed to determine how particular students re-phrased their responses POST instruction. The objective is to create a concept inventory for telecommunications and networking. This will be a new addition to the body of work based on concept inventories. The Rasch Item Response Theory (IRT) model will be utilized to analyze the effectiveness and validity of survey questions [9]. The authors will also take into account the possibility of confounding factors, which may lead to the wrong conclusions regarding the root causes of the students' misconceptions.

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