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Student and Instructor Perceptions of the Usefulness of Computer-Based Microworlds in Supporting the Teaching and Assessment of Computer Networking Skills: An Exploratory Study

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Skill shortages in the area of computer network troubleshooting are becoming increasingly acute. According to research sponsored by Cisco's Learning Institute, the demand for professionals with computer networking skills in the United States and Canada will outpace the supply of workers with those skills by an average of 8 percent per year through 2011, amounting to a shortage of about 60,000 full-time workers each year [1]. This skill shortage is having a detrimental economic effect on the Information Technology (IT) industry at large. Computer networking problem-solving or troubleshooting skills are critical to a network engineer's work and are among the most desired skill areas demanded by prospective employers who are looking for entry level network engineers [23, 26]. However, teaching and assessing these skills effectively requires a hands-on approach so that each student is individually exposed to an entire network of several computers, network switches, and network routers. This is often problematic in face-to-face teaching contexts due to time, space, and cost considerations and even more problematic in distance learning contexts where students take courses and complete degrees totally online with no physical access to a computer networking lab. Hence, the purpose of this study was to examine the usefulness of Computer-Based Micro-Worlds (CBMW) in supporting the teaching and assessment of computer networking problem-solving skills.

Specifically, the researchers hypothesized that CBMW may provide (a) an economically viable method to overcome the difficulty and expense commonly faced when training students to become effective network engineers, and (b) a practical and widely accessible learning method that could help alleviate the skill shortage in the industry. In order to determine the viability of these hypotheses, this exploratory study examined student and instructor perceptions of the usefulness of CBMW in supporting the teaching and assessment of computer networking problem solving skills. Specifically, the following research questions were investigated:

1. Do students and instructors think that traditional classroom learning can prepare students to cope with real-world computer networking problem-solving challenges?
2. Do students and instructors think that CBMW can prepare students to cope with real-world computer networking problem-solving challenges?
3. Do students and instructors think that traditional assessment methods can provide a fair and accurate measure of computer networking problem-solving skills?
4. Do students and instructors think that CBMW can provide a fair and accurate measure of computer networking problem-solving skills?

THEORETICAL FRAMEWORK

The teaching of computer networking is generally based on the concept of layered networked systems [15]. These layered network systems consist of hardware and software that interact to achieve end to end communication. One of the most commonly used models for teaching this concept is the International Standards Organization's (ISO) seven layer model for Open System Interconnection (OSI) [20]. The communication across these layers is facilitated by the use of different layer protocols such as Internet Protocol (IP) or Ethernet. Generally higher level protocols such as IP are enveloped within lower level protocols such as Ethernet. Matthews [15] reported on how he makes use of packet tracing software to capture all Ethernet traffic on computer networks and then uses the contents of those packets to help his students learn about this layering process.

Two of the layers within the OSI model called the transport and network layers support a standard called Transmission Control Protocol/Internet Protocol (TCP/IP). TCP/IP can be used for the transportation and routing of network information between computers using either a local area network (LAN) or a wide area network (WAN). A LAN generally consists of several computers all communicating via a single network cable or switch. These LANs will often cover the entire communication needs of a small office. For larger offices, however, several of these LANs must be interconnected using routers. Routers are computers that route computer network traffic (usually by using TCP/IP) to allow computers on two separate networks to communicate with each other [20].

In real world applications, it is common for a single building to have several LANs connected by routers. Routers within a building will generally link the internal networks to external WANs to allow all the computers in the building to access the Internet. In fact the Internet is a WAN that communicates via TCP/IP. A network engineer's job is to configure these network settings for a building. The network engineer has to know which computers are connected to which routers as well as how the routers are physically connected to each other [20]. This troubleshooting process is specifically related to layer 3 of the OSI model which is most often implemented using the IP protocol. While Matthews' [15]teaching focused on a broader overview of network layering and interaction, this study focused on the teaching and assessment of computer network configuration and troubleshooting within a single layer (layer 3) of the OSI model.

In order to teach students these networking concepts in an authentic (hands-on) manner, it would entail providing each student with a building full of routers and computers. However the best attempts at designing computer networking teaching labs generally involve setups that have only two computers connected to each other via a single router [3]. While these simplistic networks may be used to teach basic networking principles, it is difficult to use them to prepare students to solve the complex problems that can arise when several switches and routers have to be interconnected. A possible solution is to augment classroom experiences with CBMW to simulate complex networking situations that network engineers face in the real world.

While other more complex computer network simulators are available, a CBMW is unique in that it models the complex concepts under study in a simplified or constrained representation system (i.e., a micro-world) making it easier for learners to focus on the most important principles and processes to be learned [17, 18, 19]. A more general computer network simulator is typically more complex and would require that students learn how to configure specific models of routers as well as specific models of network adaptors. Additionally, a full scale computer network simulator would include the configuration and troubleshooting of all network layers in the OSI model whereas the CBMW designed for this study focuses on the configuration and troubleshooting of a single layer (layer 3) of the OSI model which is most often implemented using the IP protocol.

Jonassen, Carr & Yueh [13] describe CBMW as dynamic modeling tools that can act as exploratory learning environments or what they term "discovery spaces." Hannafin et al. [11] define a CBMW as representing the simplest case of a domain that is still recognizable by an expert in the domain. CBMW are used to help students investigate problems within specific subject areas that are difficult to experiment with in the real world due to time constraints or physical restrictions [4, 12]. Students learn how to set up environmental variables and parameters and then check their effects or impact in a simplified simulation of a real world situation. Rieber [19] emphasized that CBMW help focus learners on the most important relationships or rules underlying the principles and concepts of the domain being studied which is very appropriate for computer networking problem-solving skills. In addition, CBMW may become more complex as the learner progresses in guided exploration from simple to more complex forms of the learning domain [9, 19].

Perhaps the most important feature of CBMW is that they involve active learning through hypothesis testing. Learners generate a hypothesis and then test it using the programmed logic of the CBMW to simulate reality. Research has shown that the repeated generation and testing of hypotheses will result in learners building an increasingly accurate mental model of the learning situation thus providing them with the knowledge they will need to solve real world problems [17, 19]. Jonassen [12] emphasized the usefulness of the hypothesis-testing feature of CBMW in the development of critical thinking, and posited that improvements in a learner's problem solving abilities in the constrained area investigated in a CBMW may transfer well to more general critical thinking skills that can be applied in other areas.

Additionally, previous research studies have indicated that CBMW can be effective instructional tools for real world and complex problem-solving skills such as those required by computer networking students [6, 8, 21]. For example, Tao [21] recounts his use of a CBMW, Force and Motion, designed to teach the principles of Newtonian mechanics to 27 high school students. Students were tested on their knowledge of Newtonian mechanics before and after being exposed to the Force and Motion CBMW. The results of this study revealed that the greatest conceptual changes were observed in students who shifted back and forth between hypotheses by applying several different scientific concepts to their problem solving exercises. In addition, the results of this study revealed that students were very engaged in the CBMW and perceived it to be "easy to use" and that "it helped them learn the concepts being explored".

Niederhauser and Stoddart [16] greatly emphasize the importance of the open exploratory nature of CBMW and argue that while they are constrained learning spaces, the openness of CBMW means that they do not teach a specific body of facts. Rather, it is the learner who determines the questions being examined and the problems being explored. Funke [7] supported this notion and emphasized the role of mathematical modeling in the design of CBMW by stressing that the openness of CBMW is in large part due to the freedom with which the learner can interact with the control variables of a CBMW system.

Goldstone and Son [8] investigated the use of a CBMW called Educational Field Hockey (EFH) designed to help learners explore the physics of electrical interactions. Learners analyzed the effect of control strategies that they fed into the EFH by measuring how well the CBMW played the EFH game. The researchers then measured the physics knowledge acquired by students after they had been exposed to this CBMW. The results showed that knowledge transfer was not well supported when students were left to work with the CBMW without clear goals or problems to solve. Much higher learning gains were reported for students who used a guided exploration method while interacting with the CBMW.

Fitzgerald and Semrau [6] investigated the use of CBMW in teaching a group of special education instructors how to assess students with emotional and behavioral disorders. The CBMW used several student case studies and allowed the instructors to work with the subjects in the case studies as if they were dealing with real world student problems. The study investigated several variables, including prior learner computer experience, prior learner teaching experience, and engagement time (total time working on each case study). Although the findings did not show a relationship between the first two variables and the participants overall success with the CBMW outcomes, they did reveal a significant correlation between the third variable, engagement time, and participant success on the CBMW outcomes.

These research studies clearly reveal the usefulness of CBMW in supporting the teaching of problem solving and critical thinking skills such as those required in the field of computer networking. The research presented also indicates that CBMW may be most effective when they are carefully designed to ensure openness to student exploration and hypothesis testing. Furthermore, the research suggests that learners using CBMW may benefit most when the micro-world is used within a supportive and well structured environment or guided exploration. The two CBMW developed for this study integrated several of these research implications. While the instructional goal of the CBMW developed for this study was to support the teaching and assessment of computer networking problem-solving skills in college courses, the purpose of this exploratory study was to examine student and instructor perceptions of the usefulness of CBMW in preparing students to cope with the complex challenges of computer networking troubleshooting skills when they enter the workplace.

METHOD

Participants

Participants were community college IT students (*n* = 72) and computer networking course instructors (*n* = 9). Students ranged in age from 18 to 70 years. Average GPA was 3.4 and average number of prior computer networking classes taken by these student participants was 3.8. All computer networking course instructors at this postsecondary institution are required to have a minimum of a Master's Degree in a relevant subject area and two years industrial experience. Student and instructor participants originated from nine sections of the following four, semester-long (16 weeks) computer networking classes at the community college where the study took place: ITN 200, Network Administration, ITN 245, Network Servicing, ITN 208, TCP/IP, and ITN 154, Networking Fundamentals.

CBMW Structure and Functions

Two, fully functional CBMW were developed to examine the research questions proposed in this study. Both CBMW were developed to run under any Microsoft Windows operating system. The first

CBMW, the Internet Protocol Learning Microworld (IPLM), simulates complex computer network environments and allows students to experiment with hardware (Ethernet) connection changes as well as Internet Protocol (IP) configurations. The second CBMW, the Internet Protocol Assessment Microworld (IPAM), is largely identical to the IPLM but incorporates minor changes that enhance its use as an assessment tool.

More specifically, the IPLM has one main configuration screen for variable and data input (see Figure 1) and two main diagnostic screens (see Figure 2). The student begins using the IPLM by clicking and dragging the icons that represent computers, networking switches, and modems around a blank computer screen. The student can then use simulated cables to connect the virtual network cards in each simulated computer to simulated ports on the simulated network switches and modems. Each of the simulated network cables is represented on the screen using a different color in order to avoid confusing which computer is connected to which port on which network switch. In addition to controlling how the equipment will be connected, the student can also configure the Internet Protocol (IP) assignments for each simulated network card setup. Furthermore, the student

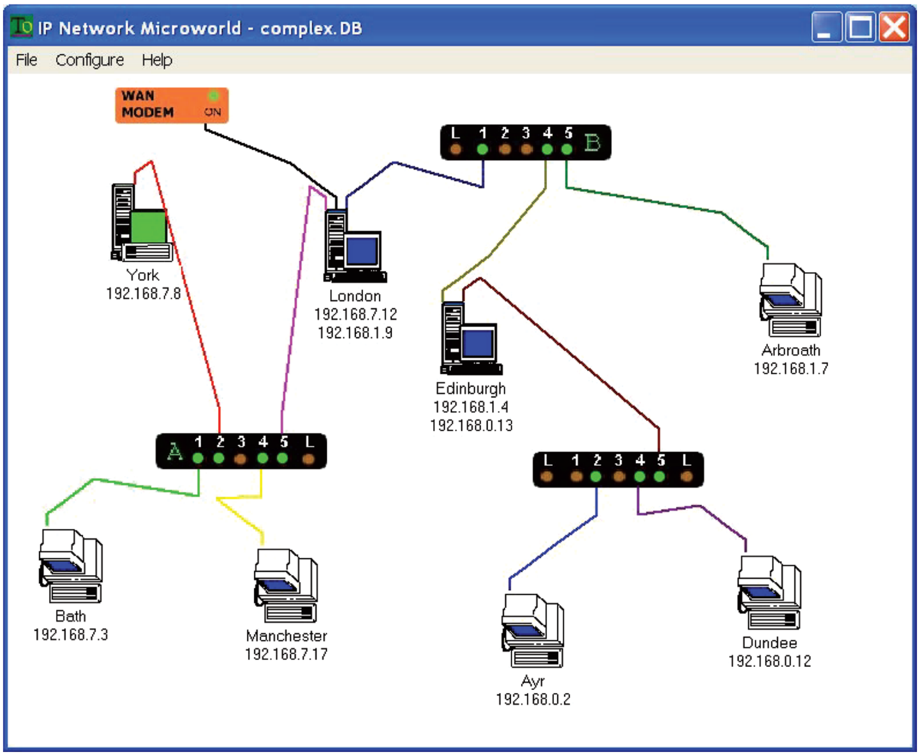


Figure 1: Network Configuration Screen.

can enable/disable and configure several simulated network services running on the simulated computers. These include a simulated Web server service, a simulated domain name server (DNS) service, a simulated dynamic host configuration protocol (DHCP) service, and a simulated routing service.

Once the student has entered a network configuration, he or she can test the communication between the different computers on the network using a simulated Web browser (Figure 2) and a simulated command shell window (Figure 3) on each computer. The simulated command shell window can be used to enter standard network troubleshooting commands to test the various connections on the simulated network. Additionally, if the computer running the IPLM CBMW has a connection to the Internet, the student can configure a simulated wide area network (WAN) modem to provide access to the Internet, in the same way that this kind of modem would provide Internet access for a small office building in the real world. The student can then use the simulated command shell and Web browser to test communication between any of the computers in the CBMW and any real-world computers and/or Internet sites.

In addition, given the emphasis the literature places on the need for problem or task structure to aid both learning and transfer to real-world situations [2, 8], it was important that the IPLM be accompanied by a well-defined assignment framework. Therefore, along with the CBMW software, the IPLM was packaged with a set of six increasingly complex computer network problem-solving tasks that students could select from. Each of these problems contained a title such as DHCP Problem as well as textual description of the problem. For example, the first problem asks the learners to do little more than input a valid IP address to two PC desktop computers and then check that communication is possible between the computers. Subsequent problems increase in complexity

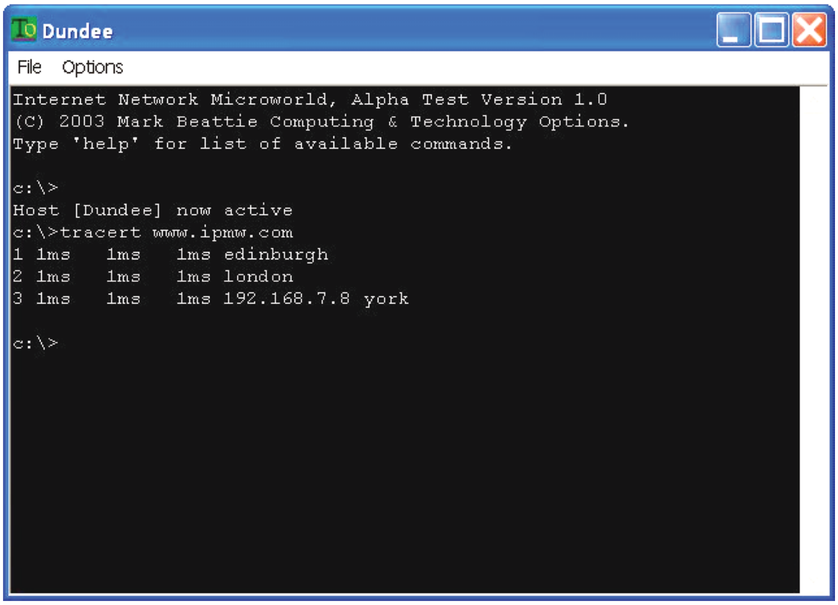
IP Microworld

You have reached the default server web page.

IP Microworld (c) 2003, (c) 2005

Mark Beattie & Technology Options,

Figure 2: Simulated Web Browser.

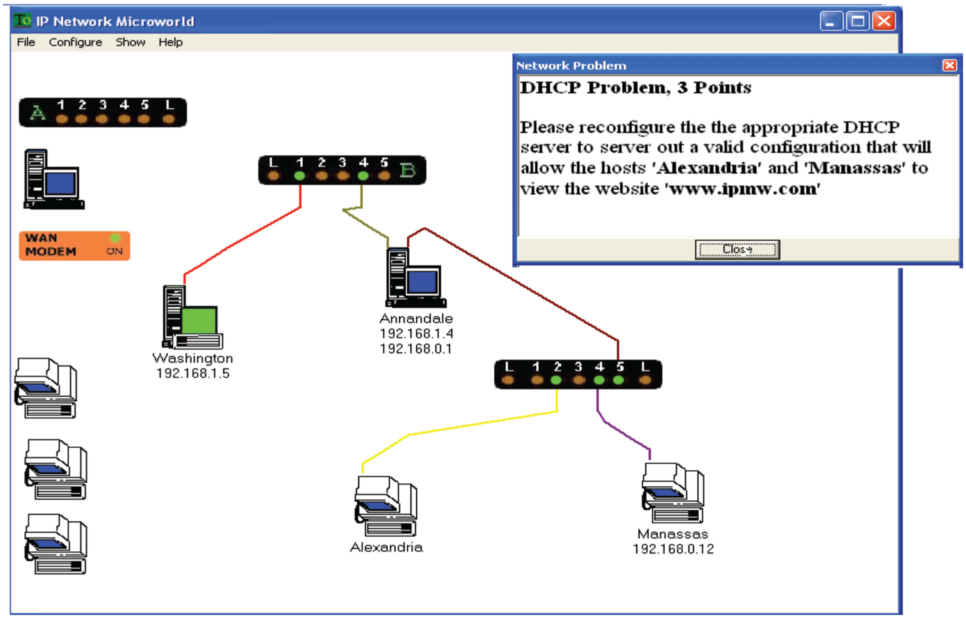


```
Internet Network Microworld, Alpha Test Version 1.0
(C) 2003 Mark Beattie Computing & Technology Options.
Type 'help' for list of available commands.

c:\>
Host [Dundee] now active
c:\>tracert www.ipmw.com
1 1ms    1ms    1ms edinburgh
2 1ms    1ms    1ms london
3 1ms    1ms    1ms 192.168.7.8 york

c:\>
```

Figure 3: Simulated Command Shell Window.



DHCP Problem, 3 Points

Please reconfigure the the appropriate DHCP server to server out a valid configuration that will allow the hosts 'Alexandria' and 'Manassas' to view the website 'www.ipmw.com'

Figure 4: Example of Computer Network Troubleshooting Problem.

such that the final problem involves eight PC desktop computers that must be correctly configured to make use of three IP subnets. Each of the problems is assigned a difficulty level point score where 1 point indicates an introductory level (easy) problem and 5 indicates an advanced level (difficult) problem. An example problem is shown in Figure 4.

Furthermore, the IPLM and IPAM were developed to promote guided exploration and experiential learning by modeling real-world computer network hardware and logic, allowing learner access to, and movement between equipment that would otherwise be bulky, cumbersome, and expensive. Furthermore, the IPLM and IPAM provide several emulated network services that run on the simulated computers. These include:

- A simple Domain Name Service (DNS) server or the Domain Controller Server.
- A simple Web server on the Domain Controller Server.
- Routing for Internet Protocol (RIP) service on each of the multi-homed servers.
- A simple Dynamic Host Configuration Protocol (DHCP) that can be configured and used as it would in the real world.

In addition, the IPLM and IPAM meet more recently defined instructional characteristics of a CBMW in that they facilitate the user's direct manipulation of the CBMW's interface to support real-world learning and problem solving by repeated hypothesis generation and testing in a compressed space and time context [4]. As part of the problem solving process, the student could dynamically make changes to IP configurations, network connections, or any of the simulated services in the IPLM CBMW and instantly test the effect of that change through the feedback received from the simulated command shell and simulated Web browser screens as depicted in Figures 2 and 3. This inherent design allows the learner to begin by building a simple network and progress into building increasingly complex networks consisting of multiple broadcast domains and real-world Internet connectivity. The progression from simple to complex cases of the learning domain is an essential characteristic of a CBMW [17, 19]. It supports students' incremental acquisition of problem-solving skills while facilitating both deductive and inductive reasoning. It also provides a learning path from the known to the unknown. Students start from simple networks that they understand and then build these into increasingly more complex networks.

Another characteristic of a CBMW is the ability to use it without instruction or guidance [17, 19]. This is of course largely dependent on the background knowledge of the users. Both the IPLM and IPAM were designed for students enrolled in networking classes and therefore these students have some prior networking knowledge enabling them to use these CBMW with little or no instruction. The CBMW also allow the instructor to prepare networks for troubleshooting, which not only contain incorrect IP settings but may also include simulated faulty network cables, faulty network cards, faulty switch ports, as well as faulty switches or a faulty WAN modem. The instructor can therefore present students with authentic troubleshooting exercises as well as assessment materials.

The assessment CBMW (IPAM) is compatible with the teaching CBMW (IPLM) in that it can load configuration files created with the teaching CBMW. However, it differs from the teaching CBMW (IPLM) in that it does not allow users to view or configure the list of simulated faulty equipment. Thus, the assessment CBMW, IPAM, more correctly reflects real-world situations where the student cannot rely on all of the computer hardware to function correctly and therefore must be able to diagnose equipment as faulty using the available troubleshooting tools within the CBMW.

Measures

Eight Likert scale type surveys were used to examine student and instructor perceptions of the usefulness of the CBMW in supporting the teaching and assessment of computer networking problem solving skills. Surveys 1 and 2 (IPS1 & IPS2) addressed the first research question of this study (participant perceptions of traditional computer networking teaching environments), surveys 3 and 4 (IPS3 & IPS4) addressed the second research question (participant perceptions of the usefulness of the teaching CBMW, IPLM), surveys 5 and 6 (IPS5 & IPS6) addressed the third research question (participant perceptions of traditional computer networking assessment techniques), and surveys 7 and 8 (IPS7 & IPS8) addressed the fourth research question (participant perceptions of the assessment CBMW, IPAM). All survey questions were on a scale of 1-5 where 1 was SD (Strongly Disagree) and 5 was SA (Strongly Agree). The number of questions in a survey ranged from 8 to 20. See Table 1 for more specific survey descriptions and Appendix for sample surveys.

Student surveys also gathered demographic information as well as information on their computer networking background knowledge and experience including the number of prior computer network classes taken. This data was later analyzed to determine if students' prior networking experience may have had an impact on their perceptions of the usefulness of the IPLM in supporting their learning. Instructor surveys also gathered their perceptions of their students' skill levels when they started their course.

Research Design and Procedure

This study implemented a quasi-experimental research design. Students in 9 computer networking classes at a community college in the mid-Atlantic region of the United States provided the context for this study. Random assignment to research groups was not possible because group assignment was based on student class membership. However, the intact classes were randomly assigned to three research groups as follows:

Survey Name	Survey Description
IPS1	Measured *student* perceptions of how well traditional teaching methods helped to develop their computer networking problem-solving skills and prepare them to solve real-world problems.
IPS2	Measured *instructor* perceptions of how well traditional teaching methods helped to develop their students' computer networking problem-solving skills and prepare them to solve real-world problems.
IPS3	Measured *student* perceptions of the usefulness of the IPLM CBMW in developing their computer networking problem-solving skills and preparing them to solve real-world problems.
IPS4	Measured *instructor* perceptions of the usefulness of the IPLM in developing their students' computer networking problem-solving skills and preparing these students to solve real-world problems.
IPS5	Measured *student* perceptions of how fairly and accurately traditional assessment techniques evaluated their computer networking problem-solving skills.
IPS6	Measured *instructor* perceptions of how fairly and accurately traditional assessment measures evaluated their students' computer networking problem-solving skills.
IPS7	Measured *student* perceptions of how fairly and accurately the IPAM CBMW was able to assess their computer networking problem-solving skills.
IPS8	Measured *instructor* perceptions of how fairly and accurately the IPAM CBMW was able to assess their students' computer networking problem-solving skills.

Table 1: Survey Descriptions.

Group One. Two classes (2 instructors and 15 students) were not exposed to any CBMW software but were surveyed about their perceptions of the usefulness of traditional computer networking instruction and assessment (addressing research questions 1 & 3).

Group Two. Two classes (2 instructors and 19 students) were exposed to both the teaching (IPLM) and the assessment (IPAM) CBMW and participants were surveyed about their perceptions of the usefulness of these CBMW in supporting their learning and assessment of computer networking problem-solving skills (addressing research questions 2 & 4).

Group Three. Five classes (5 instructors and 38 students) were exposed to the teaching CBMW (IPLM) but not the assessment CBMW. These participants were surveyed about their perceptions of the usefulness of the IPLM in supporting the development of computer networking problem-solving skills (addressing research question 2). Additionally, these participants were surveyed to examine their perceptions of the effectiveness of traditional assessment techniques (addressing research question 3).

Students were exposed to the CBMW during the last four weeks of the semester and each of the three case study groups were asked to complete the appropriate surveys according to the timeline depicted in Table 2. Student exposure to the CBMW software was in addition to their regular computer networking coursework. All students continued to take part in their regular coursework which included lectures and any traditional hands-on laboratory classes that their instructors had planned.

Group	Week 1 to 8	Week 9 to 12	Week 13 and 14	Week 15 to 16
Group One: No CBMW Exposure	Traditional Teaching and Assessment		Teaching Survey IPS1 (15 Students) IPS2 (2 Instructors) Assessment Survey IPS5 (15 Students) IPS6 (2 Instructors)	General coursework
Group Two: IPLM and IPAM Exposure	Traditional Teaching and Assessment	4 Week Exposure to Teaching CBMW (IPLM) and Assessment CBMW (IPAM)	Teaching Survey IPS3 (19 Students) IPS4 (2 Instructors) Assessment Survey IPS7 (19 Students) IPS8 (2 Instructors)	General coursework
Group Three: IPLM Exposure Only	Traditional Teaching and Assessment	4 Week Exposure to Teaching CBMW (IPLM) Only Traditional Assessment	Teaching Survey IPS3 (38 Students) IPS4 (5 Instructors) Assessment Survey IPS5 (20 Students) IPS6 (5 Instructors)	General coursework

Table 2: Procedure and Timeline.

ANALYSIS

Descriptive statistics were calculated for all the survey data. In addition, two tailed t-tests were used to look for significant differences between perceptions of students who were exposed to the CBMW technology and those who were not, using applicable and corresponding items from the appropriate case study group surveys. T-tests were also used to compare survey responses of students who indicated they had more extensive computer networking experience with those who indicated they had less computer-networking experience to see if this variable had an impact on their perceptions of the CBMW technology.

Furthermore, student engagement (number of computer networking problems attempted in the IPLM and number of hours spent using the IPLM) was analyzed to determine if there was a correlation between this variable and student perceptions of the usefulness of the IPLM in supporting their learning. During each check for statistical significance, Levene's test for equality of variances (F) was examined to see if equal variance should be assumed at the 95% confidence level. Cronbach's alphas were computed to determine the internal reliability of the surveys administered. The results revealed a range from 0.60 to 0.96 for student and instructor surveys with one student survey (IPS1) returning an alpha of 0.49 and one instructor survey (IPS8) returning a negative alpha due to small sample size and lack of variance.

RESULTS

Overall, the results of this study revealed that students and instructors had a neutral perception of the usefulness of traditional classroom teaching and assessment methods in preparing students to cope with real-world computer network problem-solving skills and challenges. Contrastingly, students and instructors exposed to the CBMW expressed significantly higher (above average) perceptions of the usefulness of CBMW in (a) preparing students to cope with real-world computer networking problem-solving challenges than traditional learning alone, and (b) in assessing students' knowledge of computer networking problem solving skills more fairly and accurately than traditional assessment methods. Further elaboration is provided by research question and type of participant (student or instructor).

Research Question One

Student perceptions. The first of the four research questions investigated in this study was "Do students and instructors think that traditional classroom learning can prepare students to cope with real-world computer network problem-solving challenges?" Students in this research study group (group one) did not rate their traditional learning environments highly (see Table 3). For example, the mean response to question one of IPS1 "Has your experience in the classroom helped prepare you to solve real-world computer networking problems?" was 2.9, which is below option 3 on the Likert scale ("it helped some"). Of the 15 students surveyed, only two responded with option 4 ("very helpful") and none responded with "extremely helpful" (option 5). Similarly, the mean response to question six of IPS1 "In general, did you think that the equipment in your class was useful for helping students learn networking problem-solving skills?" was 2.8, indicating a less than average perception of the usefulness of traditional teaching environments in supporting the learning of computer networking skills.

Analysis of this group's response to question four "How was your class taught?" indicated that on average students believed they were taught using 80% - 100% lecture style with less than 20% laboratory time (M = 1.8, see Table 3). Furthermore, a mean response of 2.7 was calculated for question 3 of IPS1, "Did you fell that you got enough hands-on computer experience in the classroom?" (See Appendix & Table 3) indicating that students were not satisfied with the degree of hands-on experience they received in the classroom. This result corresponds with the result for question 6 of

Question	N	Minimum	Maximum	Mean	Std. Deviation
Q1	15	2.00	4.00	2.9333	0.5936
Q2	15	3.00	5.00	3.4667	0.6399
Q3	15	1.00	4.00	2.6667	0.9759
Q4	15	1.00	3.00	1.8000	0.6761
Q5	15	1.00	4.00	2.5333	0.8338
Q6	15	1.00	4.00	2.8000	0.9411
Q7	15	1.00	4.00	2.3333	0.7237

Table 3: Descriptive Statistics IPS1, Learning Survey, No IPLM Exposure, Students.

IPS1 (M = 2.8) indicating that students did not express high levels of satisfaction with the effectiveness of the classroom equipment in preparing them to solve real-world troubleshooting problems even though these classes were taught in labs that were designed especially for teaching advanced computer networking courses, perhaps representing the best physical hardware that could reasonably be made available.

Instructor perceptions. Instructor survey responses for this group (group one) were mixed (see Table 4). In response to question eight (Q8) of IPS2 “In general, do you think that the current equipment in your class was useful for helping students to learn networking problem-solving skills?”, one instructor responded with a rating of 1, indicating strong dissatisfaction, and the other responded with a rating of 4, indicating high satisfaction. The instructors were using identical equipment. Not surprisingly, their responses to Q1 of IPS2, “Do you feel that your classroom work helped prepare your students to solve real-world computer networking problems?” and Q7 of ISP2 “How would you describe your typical student’s networking problem-solving abilities after they complete your class?” resulted in a mean of 3.5 for each question indicating an above average perception of the usefulness of traditional teaching environments in supporting the teaching of computer networking problem solving skills.

Research Question Two

This question examined whether participants thought that the IPLM CBMW (the teaching CBMW) can prepare students to cope with real-world computer networking problem-solving challenges. Survey data from participants in research groups two and three (those exposed to the IPLM) were compared to survey data from research group one using t-tests.

Student perceptions. Mean values on the two survey items that specifically addressed this research question in each of the student surveys (items 1&3 from IPS1 and items 1&6 from IPS3, see Appendix) were 3.6 for the IPLM groups and 2.9 for group one; and 4.5 for the IPLM groups and 2.8 for group one respectively (see Tables 3 & 5). These results were statistically significant at the

Question	N	Minimum	Maximum	Mean	Std. Deviation
Q1	2	3.00	4.00	3.5000	0.7071
Q2	2	3.00	5.00	4.0000	1.4142
Q3	2	2.00	4.00	3.0000	1.4142
Q4	2	1.00	3.00	2.0000	1.4142
Q5	2	3.00	3.00	3.0000	0.0000
Q6	2	2.00	2.00	2.0000	0.0000
Q7	2	3.00	4.00	3.5000	0.7071
Q8	2	1.00	4.00	2.5000	2.1213

Table 4: Descriptive statistics for IPS2, Learning Survey, No IPLM Exposure, Instructors.

Question	N	Minimum	Maximum	Mean	Std. Deviation
Q1	57	1.00	5.00	3.5614	1.0859
Q2	57	1.00	5.00	3.4561	1.2258
Q3	57	1.00	5.00	3.6491	1.0937
Q4	57	1.00	5.00	3.4912	1.1821
Q5	55	1.00	5.00	3.2727	1.1131
Q6	57	1.00	5.00	3.2105	1.1913
Q7	57	1.00	5.00	4.0526	1.4069
Q8	56	2.00	5.00	3.7857	0.7796
Q9	57	1.00	5.00	3.0702	0.9423
Q10	57	2.00	5.00	3.2807	0.9591
Q11	57	1.00	5.00	4.4035	0.8631
Q12	57	1.00	5.00	4.4737	0.8041
Q13	56	1.00	5.00	2.7500	1.4174
Q14	56	1.00	5.00	3.5357	1.0949
Q15	57	1.00	5.00	3.2281	1.1183
Q16	53	1.00	5.00	1.9245	1.4656
Q17	55	1.00	5.00	2.0909	1.1430

Table 5: Descriptive statistics for IPS3, Learning Survey, IPLM Exposure, Students.

95% confidence level ($t = 2.15$ & $t = 6.30$) supporting the hypothesis that students exposed to the IPLM CBMW felt better prepared to solve real-world computer networking problems than students in the classes that were not exposed to the IPLM. Additionally, students exposed to the IPLM reported stronger confidence in the CBMW's ability to help them develop their computer networking problem-solving skills compared to the level of confidence that students in group one expressed in the ability of traditional teaching environments in helping them develop their computer networking problem-solving skills.

The results were further examined to determine if the demographic data could have had an impact on students' perceptions of the IPLM. Interestingly, when compared to students in group one, students in groups 2 and 3 rated themselves significantly higher (t = 3.28 & t = 3.0) on both their prior knowledge of general networking terms and their prior computer networking problem-solving skills (question 7 in IPS1 & question 9 in IPS3) (see Appendix). This difference in rating of prior knowledge could be attributed to students' exposure to the IPLM (i.e., the Hawthorne effect) because other demographic data such as the number of prior classes taken by students in the groups examined showed no significant difference. This difference could also be attributed to the non random assignment of individual students to research groups.

With respect to the usefulness of the learning environment in helping students develop an understanding of general networking concepts, the results revealed more comparable means (M = 3.6 & M = 3.5) across the research groups that were exposed to the IPLM (groups 2 & 3) and those that were not (group 1). Question 2 in IPS1 and question 3 in IPS3 (see Appendix) were used to compute this data. This finding aligns with the expectation that while CBMW may be better at developing learners' complex problem solving skills, they are not necessarily better than traditional learning environments in developing learner understanding of more general or conceptual subject matter [5].

With respect to the effect of engagement time (question 1, ISP3) (see Appendix), responses of students who were exposed to the IPLM and had used it for less than five hours were compared to responses of students who were exposed to the IPLM and had used it for more than five hours. A statistically significant difference was found in students' perceptions of how the IPLM helped develop their problem-solving skills (<5 hours, M = 3.2; >=5 hours, M = 3.9; t = 2.47).

Instructor perceptions. Survey results of instructors who were exposed to the IPLM (*n* = 7) were compared to survey results of instructors who were not exposed to the IPLM (*n* = 2). While this is a small sample size with subsequent vulnerability to both type one and type two errors, some statistically significant differences were found across these two groups. The instructors exposed to the IPLM were asked "In general, do you think this kind of tool is useful for helping students learn networking problem-solving skills?" The instructors who were not exposed to the IPLM were asked "In general, do you think that the current equipment in your class was useful for helping students learn networking problem-solving skills?"

The mean scores on these survey items were 4.9 and 2.5 respectively which was statistically significant (t = 3.36) (see Table 6, Q11 & Table 4, Q8). In addition, instructors exposed to the IPLM were asked, "How well do you think the CBMW has helped prepare your students to solve real-world computer networking problems?" and those not exposed to the CBMW were asked, "Do you feel that your classroom work helped prepare your students to solve real-world computer networking problems?" The mean scores on these survey items were 3.6 and 3.5 respectively which was not found to be statistically significant.

Research Question Three

The third research question of this study was “Do students and instructors think that traditional assessment tools can provide a fair and accurate measure of computer networking problem-solving skills?” In order to answer this question, the survey data from all students and instructors not exposed to the IPAM CBMW (groups 1 and 3) was examined. The surveys used were student survey IPS5 and instructor survey IPS6.

Student perceptions. Students in the traditional assessment groups were asked “Do you think that the current equipment in your class is sufficient for assessing your networking problem-solving skills?” The mean response was 3.0 (“Acceptable”) (See Table 7, Q7). They were also asked “How accurately do you feel that your classroom assessments are able to measure your ability to solve real-world computer networking problems?” The mean response was 2.7 (between “Reasonably Accurate” and “Not Very Accurate”) (See Table 7, Q1).

Instructor perceptions. Instructors (*n* = 7) who were not exposed to the assessment CBMW (IPAM) showed a high level of agreement (M = 4.1) when asked how important they felt it was to assess problem-solving skills (see Table 8, Q6). However, when asked if they made a specific effort to assess problem solving skills (see Table 8, Q4), the mean response was lower (M = 3.1). The majority of these instructors indicated that their students had been assessed 100% by written examination. One instructor indicated using 80% written examination and 20% practical or performance-based assessment, one instructor did not respond, and one instructor indicated using 80% performance-based

Question	N	Minimum	Maximum	Mean	Std. Deviation
Q1	7	3.00	4.00	3.5714	0.5345
Q2	7	2.00	5.00	3.5714	0.9759
Q3	7	3.00	5.00	4.0000	0.8165
Q4	6	3.00	5.00	3.7143	0.9512
Q5	7	3.00	5.00	3.7143	0.9512
Q6	7	1.00	5.00	4.2857	1.4960
Q7	7	3.00	5.00	4.1429	0.6901
Q8	7	2.00	5.00	3.1429	1.2150
Q9	7	2.00	4.00	3.1429	0.8997
Q10	7	4.00	5.00	4.7143	0.4880
Q11	7	4.00	5.00	4.8571	0.3780
Q12	7	3.00	5.00	4.1429	0.6901
Q13	7	3.00	5.00	4.2857	0.7559
Q14	7	1.00	5.00	3.2857	1.3801
Q15	7	1.00	5.00	2.0000	1.5275

Table 6: Descriptive statistics for survey IPS4, Learning Survey, IPLM Exposure, Instructors.

assessment and 20% written examination. The mean response to Q1 (see Table 8) “How accurately do you feel that your classroom assessments are able to measure your students’ ability to solve real-world computer networking problems?” was 3.1 (slightly above “reasonably accurately”).

Research Question Four

The fourth of the four research questions this study investigated was “Do students and instructors think CBMW can provide a fair and accurate measure of computer networking problem-solving skills?” Descriptive statistics for the survey responses from the students and instructors who were exposed to the assessment CBMW were examined and compared to the survey responses of students and instructors who were not exposed to the assessment CBMW (see Tables 7, 8, 9, & 10). These results were examined for statistical significance using t-tests.

Student perceptions. The students surveyed were asked two main questions to measure their perceptions of the effectiveness of IPAM as a tool for assessing problem-solving skills. The first question asked generally if students thought that CBMW are useful tools for assessing problem-solving skills and the second question asked whether students felt that their problem-solving skills had been fairly assessed by the IPAM tool. Corresponding questions were asked of students not exposed to IPAM. Perceptions of students who were exposed to IPAM were compared to perceptions of students who were assessed using traditional methods. Results revealed that students exposed to IPAM expressed significantly higher satisfaction (t = 5.67) with the appropriateness of IPAM (M = 4.5) in assessing their computer networking problem solving skills compared to those assessed by traditional methods (M = 3.0).

With respect to fairness, students exposed to IPAM were asked “Do you think that this kind of assessment fairly measured your real-world problem-solving skills?” Alternatively, those assessed using traditional measures were asked “How accurately do you feel that your classroom assessments are able to measure your ability to solve real-world computer networking problems?” The results revealed that students exposed to IPAM expressed a significantly higher level of satisfaction with

Question	N	Minimum	Maximum	Mean	Std. Deviation
Q1	35	1.00	5.00	2.7714	1.0025
Q2	35	1.00	5.00	2.1143	0.9933
Q3	35	1.00	5.00	2.8571	1.0612
Q4	35	1.00	5.00	3.0857	1.2689
Q5	34	1.00	5.00	2.4412	1.1333
Q6	35	2.00	5.00	4.2000	0.8331
Q7	34	1.00	5.00	3.0000	1.1807

Table 7: Descriptive statistics for IPS5, Assessment Survey, No IPAM Exposure, Students.

the fairness of IPAM (M= 4.1; t = 4.82) compared to students who were assessed using traditional methods (M=2.8) (see Table 7, Q1 & Table 9, Q2).

Instructor perceptions. In order to measure instructor perceptions of IPAM, the instructors who were exposed to IPAM (*n*=2) were asked "In general, do you think this kind of tool is useful for assessing networking problem-solving skills?" Instructors not exposed to IPAM (*n* = 7) were asked "In general, do you think that the current equipment in your class was sufficient for assessing your students' networking problem-solving skills?" Results revealed that instructors exposed to the IPAM expressed a significantly higher perception of its usefulness as an assessment tool (M = 5.0; t = 4.0) compared to the instructors using traditional assessment methods (M = 3.1) (see Table 10, Q12 & Table 8, Q7).

In addition, instructors' perceptions of how fairly their students' computer networking problem-solving skills were assessed by IPAM were compared to instructors perceptions of how fairly

Question	N	Minimum	Maximum	Mean	Std. Deviation
Q1	7	2.00	4.00	3.1429	0.6901
Q2	6	1.00	4.00	1.8333	1.1690
Q3	7	3.00	5.00	3.8571	0.8997
Q4	7	1.00	5.00	3.1429	1.3452
Q5	7	1.00	5.00	3.2857	1.4960
Q6	7	3.00	5.00	4.1429	0.8997
Q7	7	2.00	4.00	3.1429	0.8997

Table 8: Descriptive Statistics for IPS6, Assessment Survey, No IPAM Exposure, Instructors.

Question	N	Minimum	Maximum	Mean	Std. Deviation
Q1	19	3.00	5.00	4.1053	0.6578
Q2	18	3.00	5.00	4.0556	0.8726
Q3	19	3.00	5.00	4.2632	0.6534
Q4	19	3.00	5.00	4.1579	0.7647
Q5	19	3.00	5.00	4.1053	0.6578
Q6	19	3.00	5.00	3.9474	0.9113
Q7	19	1.00	5.00	3.5263	1.4670
Q8	19	2.00	5.00	4.1053	0.7375
Q9	19	2.00	5.00	3.5263	0.9048
Q10	19	2.00	5.00	3.7368	0.8057
Q11	19	2.00	5.00	4.5789	0.7685
Q12	19	2.00	5.00	4.5263	0.7723
Q13	19	1.00	5.00	2.6316	1.0651
Q14	19	3.00	5.00	4.2632	0.6534

Table 9: Descriptive statistics for IPS7, Assessment Survey, IPAM Exposure, Students.

Question	N	Minimum	Maximum	Mean	Std. Deviation
Q1	2	4.00	5.00	4.5000	0.7071
Q2	2	4.00	5.00	4.5000	0.7071
Q3	2	4.00	5.00	4.5000	0.7071
Q4	2	4.00	5.00	4.5000	0.7071
Q5	2	3.00	4.00	3.5000	0.7071
Q6	2	3.00	3.00	3.0000	0.0000
Q7	2	4.00	5.00	4.5000	0.7071
Q8	2	5.00	5.00	5.0000	0.0000
Q9	2	2.00	4.00	3.0000	1.4142
Q10	2	3.00	4.00	3.5000	0.7071
Q11	2	5.00	5.00	5.0000	0.0000
Q12	2	5.00	5.00	5.0000	0.0000
Q13	2	2.00	5.00	3.5000	2.1213
Q14	2	5.00	5.00	5.0000	0.0000

Table 10: Descriptive statistics IPS8, Assessment Survey, IPAM Exposure, Instructors.

traditional assessment methods measured their students' computer networking problem-solving skills. Instructors exposed to IPAM were asked "Do you think that this kind of assessment fairly measured your students' real world problem-solving skills?" Instructors not exposed to IPAM were asked "How accurately did you feel that your classroom assessment methods measured your students' abilities to solve real-world computer networking problems?" The results revealed a mean response of 4.5 for instructors exposed to the IPAM ($n = 2$) and a mean response of 3.1 for instructors using traditional assessment methods ($n = 7$). The difference was not statistically significant (see Table 10, Q2 & Table 8, Q1).

DISCUSSION

The results of this exploratory study provide strong support to the argument that CBMW can be perceived as useful, inexpensive tools that facilitate the development of computer networking problem-solving skills in community college students. The results revealed that overall, students and instructors perceived CBMW to be more useful than traditional learning environments in supporting the teaching and assessment of computer networking problem-solving skills. These findings are consistent with previous research cited in this paper [4, 17, 19, 10, 12], which showed that CBMW are more effective for developing complex skills such as problem-solving and critical thinking rather than factual knowledge. These findings are also consistent with research that revealed a significant relationship between student satisfaction in their perceived computing ability and satisfaction in their perceived analytical and problem solving skills [24].

Additionally, while the results of this study revealed no significant differences between the number of prior classes taken (i.e., background knowledge), and the perceived benefits of the CBMW, the results did reveal a significant correlation between time spent using the CBMW and its perceived benefits. This finding supports the work of Fitzgerald and Semrau [6] who found that learning benefits from CBMW is more a function of the time spent using the CBMW rather than the background experience of the learner. The results of this study also provided strong support for the argument that CBMW may be perceived as a more accurate assessment tool for computer networking problem solving skills than traditional assessment methods. This finding is particularly significant in that it shows that CBMW may be more effective assessment tools than other authentic or outcome based assessments [22].

Overall, the results of this exploratory study support the feasibility, practicality, and usefulness of using computer-based CBMW to teach and assess complex computer networking problem-solving skills. The ongoing shortage of skilled employees in computer network troubleshooting has been worsened by the associated difficulties and expense of effectively training new employees in this technical area. As described earlier, this is a significant problem affecting the growth of industry and commerce in the United States and other countries. CBMW such as the ones investigated in this study are affordable and economical instructional tools or technologies that allow instructors to place greater emphasis on teaching real-world computer network problem-solving skills by providing learners with a genuine hands-on real-world problem-solving experience to better prepare them for the workplace.

However the results of this study should be treated with caution. First, the lack of true random assignment weakens the external validity of the findings and prevents the generalization of these results to the general population. Second, the reliability of the research design is somewhat weakened by the small samples sizes in some of the research groups. This is particularly true of the instructor surveys. Third, the reliability index of IPS1, the survey that measured student perceptions of how well traditional teaching methods helped to develop their computer networking problem-solving skills was below the accepted 0.60 Cronbach Alpha level [14]. Additionally, the reliability index of IPS8, the survey that measured *instructor* perceptions of how fairly and accurately the IPAM CBMW was able to evaluate their students' computer networking problem-solving skills could not be calculated due to the small sample size and lack of variance. Therefore, more research is needed to validate the reliability of those surveys and subsequently the related results. Despite these limitations, the findings of this study can be considered valid in that they successfully measured both student and instructor *perceptions* within the context of a quasi-experimental exploratory case study.

This study was not designed to quantitatively measure the degree to which CBMW are useful tools; rather, this study set out to measure the perceptions of students and instructors towards the usefulness of using CBMW to teach and assess computer networking problem solving skills. It is hoped that this study has provided significant insight about these perceptions from a relatively high number of participants (72 student survey respondents) so as to encourage conducting more empirical research in this area.

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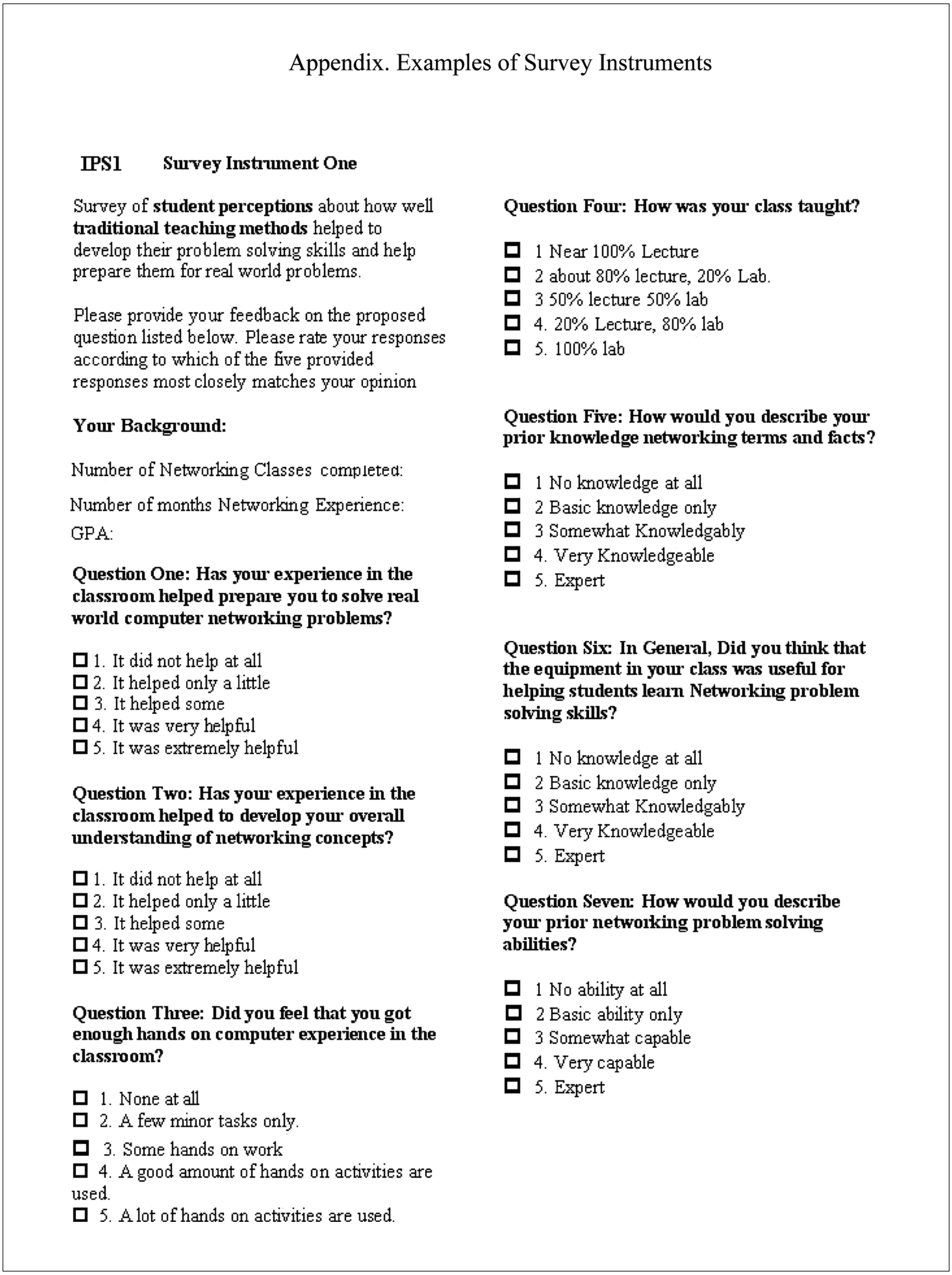


Appendix. Examples of Survey Instruments

IPS1 Survey Instrument One

Survey of **student perceptions** about how well **traditional teaching methods** helped to develop their problem solving skills and help prepare them for real world problems.

Please provide your feedback on the proposed question listed below. Please rate your responses according to which of the five provided responses most closely matches your opinion

Your Background:

Number of Networking Classes completed:

Number of months Networking Experience:

GPA:

Question One: Has your experience in the classroom helped prepare you to solve real world computer networking problems?

☐ 1. It did not help at all
☐ 2. It helped only a little
☐ 3. It helped some
☐ 4. It was very helpful
☐ 5. It was extremely helpful

Question Two: Has your experience in the classroom helped to develop your overall understanding of networking concepts?

☐ 1. It did not help at all
☐ 2. It helped only a little
☐ 3. It helped some
☐ 4. It was very helpful
☐ 5. It was extremely helpful

Question Three: Did you feel that you got enough hands on computer experience in the classroom?

☐ 1. None at all
☐ 2. A few minor tasks only.
☐ 3. Some hands on work
☐ 4. A good amount of hands on activities are used.
☐ 5. A lot of hands on activities are used.

Question Four: How was your class taught?

☐ 1 Near 100% Lecture
☐ 2 about 80% lecture, 20% Lab.
☐ 3 50% lecture 50% lab
☐ 4. 20% Lecture, 80% lab
☐ 5. 100% lab

Question Five: How would you describe your prior knowledge networking terms and facts?

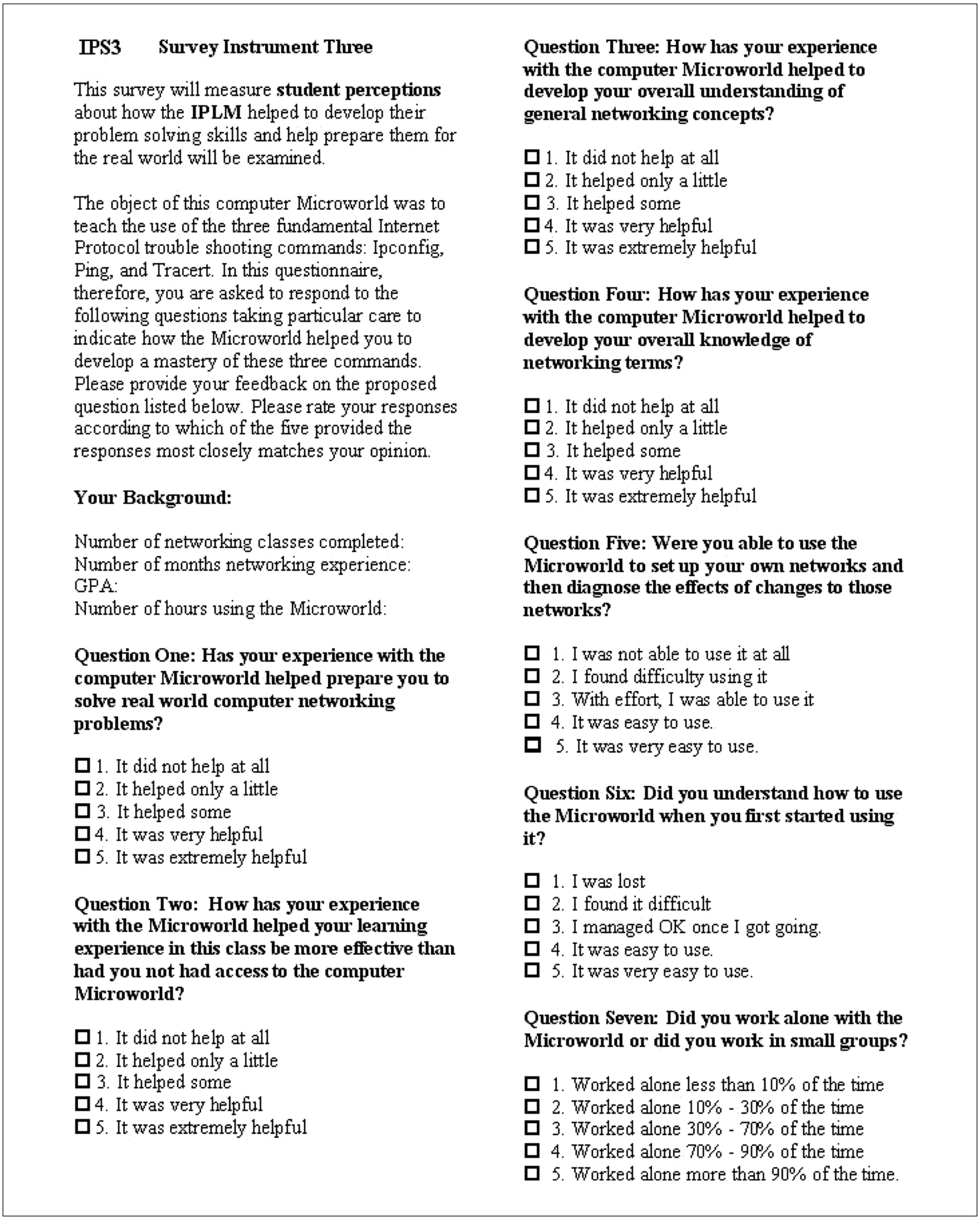
☐ 1 No knowledge at all
☐ 2 Basic knowledge only
☐ 3 Somewhat Knowledgably
☐ 4. Very Knowledgeable
☐ 5. Expert

Question Six: In General, Did you think that the equipment in your class was useful for helping students learn Networking problem solving skills?

☐ 1 No knowledge at all
☐ 2 Basic knowledge only
☐ 3 Somewhat Knowledgably
☐ 4. Very Knowledgeable
☐ 5. Expert

Question Seven: How would you describe your prior networking problem solving abilities?

☐ 1 No ability at all
☐ 2 Basic ability only
☐ 3 Somewhat capable
☐ 4. Very capable
☐ 5. Expert



IPS3 Survey Instrument Three

This survey will measure **student perceptions** about how the **IPLM** helped to develop their problem solving skills and help prepare them for the real world will be examined.

The object of this computer Microworld was to teach the use of the three fundamental Internet Protocol trouble shooting commands: Ipconfig, Ping, and Tracert. In this questionnaire, therefore, you are asked to respond to the following questions taking particular care to indicate how the Microworld helped you to develop a mastery of these three commands. Please provide your feedback on the proposed question listed below. Please rate your responses according to which of the five provided the responses most closely matches your opinion.

Your Background:

Number of networking classes completed:
Number of months networking experience:
GPA:
Number of hours using the Microworld:

Question One: Has your experience with the computer Microworld helped prepare you to solve real world computer networking problems?

☐ 1. It did not help at all
☐ 2. It helped only a little
☐ 3. It helped some
☐ 4. It was very helpful
☐ 5. It was extremely helpful

Question Two: How has your experience with the Microworld helped your learning experience in this class be more effective than had you not had access to the computer Microworld?

☐ 1. It did not help at all
☐ 2. It helped only a little
☐ 3. It helped some
☐ 4. It was very helpful
☐ 5. It was extremely helpful

Question Three: How has your experience with the computer Microworld helped to develop your overall understanding of general networking concepts?

☐ 1. It did not help at all
☐ 2. It helped only a little
☐ 3. It helped some
☐ 4. It was very helpful
☐ 5. It was extremely helpful

Question Four: How has your experience with the computer Microworld helped to develop your overall knowledge of networking terms?

☐ 1. It did not help at all
☐ 2. It helped only a little
☐ 3. It helped some
☐ 4. It was very helpful
☐ 5. It was extremely helpful

Question Five: Were you able to use the Microworld to set up your own networks and then diagnose the effects of changes to those networks?

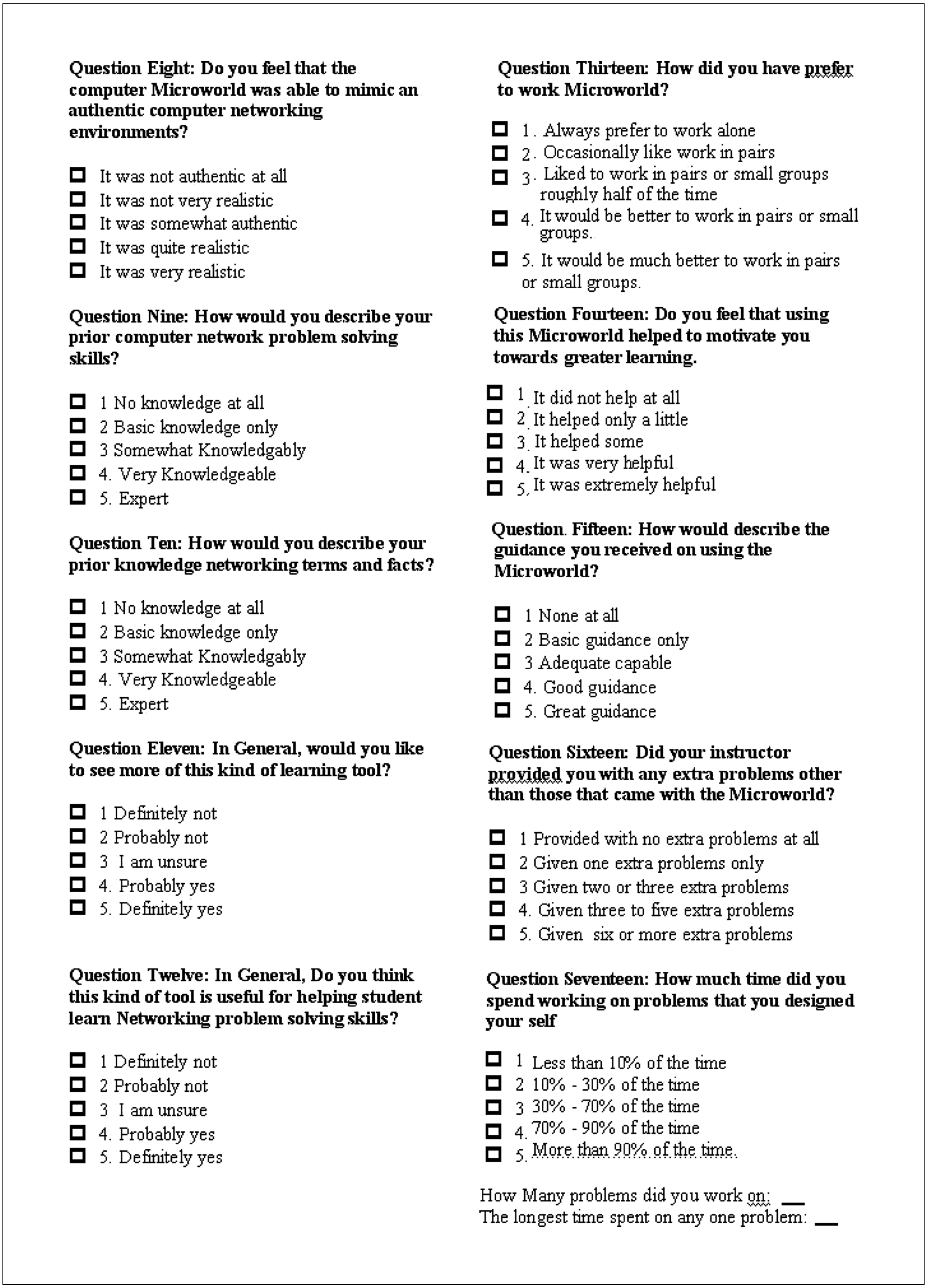
☐ 1. I was not able to use it at all
☐ 2. I found difficulty using it
☐ 3. With effort, I was able to use it
☐ 4. It was easy to use.
☐ 5. It was very easy to use.

Question Six: Did you understand how to use the Microworld when you first started using it?

☐ 1. I was lost
☐ 2. I found it difficult
☐ 3. I managed OK once I got going.
☐ 4. It was easy to use.
☐ 5. It was very easy to use.

Question Seven: Did you work alone with the Microworld or did you work in small groups?

☐ 1. Worked alone less than 10% of the time
☐ 2. Worked alone 10% - 30% of the time
☐ 3. Worked alone 30% - 70% of the time
☐ 4. Worked alone 70% - 90% of the time
☐ 5. Worked alone more than 90% of the time.



Question Eight: Do you feel that the computer Microworld was able to mimic an authentic computer networking environments?

☐ It was not authentic at all
☐ It was not very realistic
☐ It was somewhat authentic
☐ It was quite realistic
☐ It was very realistic

Question Nine: How would you describe your prior computer network problem solving skills?

☐ 1 No knowledge at all
☐ 2 Basic knowledge only
☐ 3 Somewhat Knowledgably
☐ 4. Very Knowledgeable
☐ 5. Expert

Question Ten: How would you describe your prior knowledge networking terms and facts?

☐ 1 No knowledge at all
☐ 2 Basic knowledge only
☐ 3 Somewhat Knowledgably
☐ 4. Very Knowledgeable
☐ 5. Expert

Question Eleven: In General, would you like to see more of this kind of learning tool?

☐ 1 Definitely not
☐ 2 Probably not
☐ 3 I am unsure
☐ 4. Probably yes
☐ 5. Definitely yes

Question Twelve: In General, Do you think this kind of tool is useful for helping student learn Networking problem solving skills?

☐ 1 Definitely not
☐ 2 Probably not
☐ 3 I am unsure
☐ 4. Probably yes
☐ 5. Definitely yes

Question Thirteen: How did you have prefer to work Microworld?

☐ 1. Always prefer to work alone
☐ 2. Occasionally like work in pairs
☐ 3. Liked to work in pairs or small groups roughly half of the time
☐ 4. It would be better to work in pairs or small groups.
☐ 5. It would be much better to work in pairs or small groups.

Question Fourteen: Do you feel that using this Microworld helped to motivate you towards greater learning.

☐ 1. It did not help at all
☐ 2. It helped only a little
☐ 3. It helped some
☐ 4. It was very helpful
☐ 5. It was extremely helpful

Question. Fifteen: How would describe the guidance you received on using the Microworld?

☐ 1 None at all
☐ 2 Basic guidance only
☐ 3 Adequate capable
☐ 4. Good guidance
☐ 5. Great guidance

Question Sixteen: Did your instructor provided you with any extra problems other than those that came with the Microworld?

☐ 1 Provided with no extra problems at all
☐ 2 Given one extra problems only
☐ 3 Given two or three extra problems
☐ 4. Given three to five extra problems
☐ 5. Given six or more extra problems

Question Seventeen: How much time did you spend working on problems that you designed your self

☐ 1 Less than 10% of the time
☐ 2 10% - 30% of the time
☐ 3 30% - 70% of the time
☐ 4. 70% - 90% of the time
☐ 5. More than 90% of the time.

How Many problems did you work on: __
The longest time spent on any one problem: __