Table 1: Middle School Results

Question	(Pre-/Post-) Population	Pre-Quiz	Post-Quiz
True/False	22/15	3.59	4.53
Best Practices	22/13	2.27	2.62
Conf./Using	17/10	4.14	4.30
Conf./Understanding	17/10	2.50	3.70

All populations were given a pre-quiz prior to the workshop and post-quiz at the end of the workshop that contained identical questions. Figure 2 shows a listing of sample questions. To discourage guessing, an "I don't know" option was added to each question. The first set of questions were a series of True/False questions designed to assess students' knowledge about networks, packets, WireShark, and implications of using a network. Since the first workshop was limited to only an hour, the quiz taken by the Middle School population contained only the first 6 questions. The 90-minute workshops given to the high school students were expanded to contain all 10 True/False questions. The next question asked students to circle good practices to stay safe on the Internet. Lastly, we asked students to rate (on a Likert scale) how confident they were about using computers vs. understanding how networks/the Internet works.

5 RESULTS

Results for the three populations are shown in Tables 1- 3. For the True/False questions, the authors gave a point to every question that was answered correct (an incorrect response or an "I don't know" response was assigned zero points). Hence, the maximum score that a student could earn on the True/False questions in the middle school and high school workshops was 6 and 10 respectively. For the Good Practices question, the authors counted the number of correct circles ("use encryption", "turn off GPS location posting" and "regularly check your privacy settings") and the maximum score was 3.

We used the R package [25] to conduct significance analysis. Due to the variations in the population sizes, R automatically selected a Welch two-sample t-test for this analysis.

5.1 Results with Middle School Students

Table 1 summarizes our results with the Middle School population. As previously mentioned, we were restricted to no more than an hour with this group of students. For the True/False component of the quiz, we saw an improvement from 3.59 (59.8%) to 4.53 (75.5%). We also noticed a reduction on the number of "I don't know" responses; 16 middle school students indicated at least one "I don't know" answer to True/False questions on the pre-quiz, compared to 3 on the post-quiz.

The students did fairly well on the Best Practices question on the pre-quiz and post-quiz. We speculate this could be due to prior exposure to computing topics. As mentioned, the Middle School population consisted of students who were part of the school's coding club. Only two students selected "I don't know" for this question on the pre-quiz (and none did on the post-quiz). While we see a rise in the average score on this question, it was slight.

Lastly, we asked the students to self assess their confidence in "using computers" vs. "understanding how computers and networks work". The middle schoolers were already very confident *using* computers prior to the workshop, and remained so afterwards. However, a different story emerges when middle schoolers were asked to self report their confidence on "how computers and networks work". The average score increased from 2.5 to 3.7 from the pre-quiz to the post-quiz, indicating that student confidence on understanding how computers and networks worked improved as a result of our workshop. Students also reported enjoying reading the comics and became invested in the story (*I wish Ruby was my cat!*, exclaimed one middle school student).

There were several threats to the validity of this initial study, several of which caused us to redesign the workshop for our high school populations. The biggest threat to validity were students failing to complete all questions on the pre-quiz and post-quiz, primarily due to students getting distracted and parents coming to pick up their children earlier than anticipated. Early departures and distracted students resulted in 7 students leaving without taking the post-quiz. Of the remaining 16 students who took the post-quiz, only 13 completed the Best Practices question, and only 10 answered the confidence questions. While we had attempted to number the quizzes to keep track of which students took what quiz, the classroom separated the area that students sat to take the quizzes from the area they completed the workshop. Students did not return to their original seats after the activity, removing our ability to correlate pre- and post-quiz scores. Thus, significance results are omitted for this workshop.

5.2 Results with High School Students

Our issues with the Middle School population forced us to re-evaluate how our assessments were conducted. Our high school workshops were located in a classroom with sufficient power supplies at each desk, so that students did not move around during the workshop. The workshops for high school students were 90-minutes each, enabling us to extend the True/False component of the quiz to 10 total questions. The confidence questions were modified specifically assess student confidence on understanding how the Internet works, and how to stay safe online.

Despite our best efforts, there were still a couple instances where students skipped questions or did not complete the post-quiz. Of the 16 students in the Charter School population, all completed the True/False questions, 15 completed the Best Practices question and 12-14 completed the confidence questions. While 14 students started the workshop in the Public School population, one student left early due to feeling unwell; data on at most 13 students were consequently collected. While 13 students completed both the True/False and Best Practices questions, only 9 students answered the confidence questions. Unlike our first workshop, we were able to correlate the scores in the high school populations, enabling us to perform a two-sample paired t-test.

Table 2 and Table 3 depict the improvements in average score for each question and the associated p-values. Despite attempting to make the True/False question component harder, we saw a statistically significant improvement in student performance in both populations. For example, the Charter School population averaged 50% on the pre-quiz compared to 63.1% on the post-quiz. The Public School population experienced a larger improvement, with a jump

Table 2: Charter School Results

Question	(Pre-/Post-) Population	Pre-Quiz	Post-Quiz	P-value
True/False	16/16	5.00	6.31	0.0239
Best Practices	15/15	1.80	2.23	0.0484
Conf./Using	14/14	3.50	3.79	0.5000
Conf./Understanding	13/13	2.92	3.62	0.0019
Conf./Safety	12/12	3.16	4.00	0.0172

Table 3: Public School Results

Group	(Pre-/Post-) Population	Pre-Quiz	Post-Quiz	P-value
True/False	13/13	3.92	6.69	0.0014
Best Practices	13/13	1.54	2.46	0.0148
Conf./Using	9/9	4.16	4.16	1.0000
Conf./Understanding	9/9	2.78	3.67	0.2249
Conf./Safety	8/8	2.94	4.13	0.0371

in average score from 39.2% to 66.9% on the True/False component. A reduction in the number of "I don't know" responses for the True/False component can also be observed for both populations. While 9 students from the Charter School population and 13 students from the Public School population indicated at least one "I don't know" answer on the pre-quiz, only 4 Charter School students and 4 Public School students indicated at least one "I don't know" response on the post-quiz.

The high school populations also experienced a statistically significant improvement in average scores for the Best Practices question. The Charter school population's average score improved from 1.68 to 2.23, while the Public School population improved from 1.54 to 2.46. Only 2 students from the Charter School populations indicated "I don't know" for the Best Practices question on the pre-quiz, compared to 3 from the Public School population. No students from either population selected this response on the post-quiz.

5.2.1 Confidence Analysis. The high school populations were also asked to self-assess their confidence levels on using a computer vs. "understanding how the Internet works" and "what you need to stay safe on the Internet". Responses from individuals who did not complete the associated question on both the pre-quiz and the post-quiz were excluded. We were able to procure 22 responses on "understanding how the Internet works" and 20 responses on staying "safe on the Internet". Like the Middle School population, the students from the high school populations were already very confident on using computers. Both high school populations showed an improvement in confidence from the pre-quiz to the post-quiz in understanding how the Internet works. While the Public School population's average confidence level increased from 2.78 to a 3.67 from the pre-quiz to the post-quiz, the result was not found to be significantly significant. Further analysis revealed that the confidence scores for three individuals in the Public School population actually went down. We speculate that the decrease may have been due to initial overconfidence, and that our workshop may have showed them how little they understood about the Internet to begin with.

However, there was a statistically significant increase in confidence in both high school populations on staying safe online. The Charter School population's average confidence rating increased from 3.16 on the pre-quiz to a 4.00 on the post-quiz. The Public School population's average confidence rating increased from a 2.94 to a 4.13. Our results suggest that our workshops significantly improved student confidence on staying safe on the Internet.

Figure 3: Big takeaway from the workshop

5.2.2 Open-Ended Responses. Our results are bolstered by the set of open-ended responses we received from our high school students. We asked students to note "what was the one thing (good or bad) that you took away from this workshop?". We received a total of 14 responses. Figure 3 shows a summary of the responses. We removed punctuation, capitalization, and stop words and applied stemming to merge similar words (e.g. "learn" and "learned"). In general, students were most impacted by the fact that others can "snoop" on their network traffic using a tool like Wireshark. *It doesn't take much to be a hacker*, noted one participant. *Internet safety matters!* exclaimed another.

6 CONCLUSIONS & FUTURE WORK

In this paper, we introduce *The Adventures of ScriptKitty*, a novel educational aid to teach adolescents about Internet safety through hands-on exercises on the Raspberry Pi. Our freely available materials makes *The Adventures of ScriptKitty* easy to deploy in a home or classroom setting. The current set of chapters match many of the CSTA K-12 objectives related to Networks, the Internet and social impacts. Lastly, the concepts covered in several chapters align with several GenCyber concepts, suggesting that the *ScriptKitty* materials can easily be integrated into existing GenCyber curricula.

We ran a pilot study on 51 middle school and high school students. Our results show that our materials were well received and had a significant impact on student learning of basic networking concepts. Student confidence on understanding how networks/the Internet works and how to stay safe online also increased considerably. While further assessment is needed to evaluate the *ScriptKitty* password security module, our preliminary results are promising and suggest that our materials are successful in educating students about key topics while building confidence in an important skillset.

There are many avenues for future work. To expand the ethical discussions of *The Adventures of ScriptKitty*, we plan to partner with Comic-BEE [26] to create interactive storylines with more decision making. We believe that having a more heavily-comic focused

approach will improve student engagement, especially amongst younger audiences. While our middle school students thoroughly enjoyed reading the comics, they did not enjoy reading large blocks of text accompanying the technical components. Increasing the concentration of comics in the materials will be a primary focus going forward. We also plan to run additional workshops to generate additional feedback to continue to improve the *ScriptKitty* materials and assess the remainder of the chapters.

The use of the materials in conjunction with the Raspberry Pi was a clear success. All of our populations thoroughly enjoyed using the Raspberry Pi. Educators at other institutions have also started using the *ScriptKitty* materials with elementary school students, and reported back to us that students loved the storyline and playing with the Raspberry Pi. While formal assessment of this group is not yet available, we do want to expand the *ScriptKitty* materials to cover a greater range of Internet safety topics and complete assessment with younger populations.

7 ACKNOWLEDGEMENTS

The *Adventures of ScriptKitty* was created and drawn by the first two authors while they were undergraduates at the U.S. Military Academy. The last two authors were the faculty advisors on the project. Karlee Scott also assisted in drawing comics and survey design in the early stages of the project. We also thank Raymond Blaine and Joe Sagisi for assisting with the high school workshops. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Army, Department of Defense or the U.S. Government.

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