Literature and Research Review

It is no secret that many deaf students struggle with various courses in the Golisano College of Computing Information and Science department. While there are many theories about their dismal performance, indolence is not one of them. Past research has concluded that deaf students on average do not have the skills to benefit from instructions at the same level as their hearing peers. Most methods of instruction are not optimally designed for deaf students (Marschark, 2004). While this project is not focused on placing blame on any educational institute or curriculum, it is important to acknowledge that deaf students often have different learning styles than their hearing peers.

All people have different preferences in learning styles due to different educational backgrounds and physical limitations. Learning styles can be broken into three basic categories: auditory, visual and kinesthetic. (Clark, 2000) Deaf students at RIT are inherently visual learners to a varying degree. Because they lack the ability to hear, they rely more on vision to compensate for their lack of hearing. This is called sensory compensation. (Marschark, Lang, Albertini 2000.) Therefore, they are compelled to learn and process new concepts in a different manner than auditory learners, which processes information from what they hear. Visual learners like to see a demonstration or some type of process of how things are done. They learn primarily with their eyes and rely on them to understand concepts better. (Smith, 2003) To learn a concept visually is not limited to printed materials, but can include a variety of presentation

methods that exhibits clear demonstrations of concepts. Aspects such as concrete examples, graphs, charts and visual representations of concepts are vital for visual learners. Although a teacher may attempt to include elements from each category, time limitations or other factors often prevent ideal structuring of the course to fit visual learner's needs.

One of the disadvantages that deaf students face is that they often rely solely on what they see to gather information. They need adequate time to thoroughly view visual materials, and then watch the presenter or interpreter's explanation. For instance, teachers often use a PowerPoint slide with some type of content on the screen. The deaf students are often constrained to make a decision to either read the information on the screen or to watch the interpreter translate the teacher's explanation. Regardless of which choice they make, some amount of information will be missing. Instructors often do not allow enough time for students to see both the interpreter and the visual information presented. As Rita Flattery said, "Since vision is a deaf person's primary channel to receive information…..visual aids are a tremendous help." (Flattery) All this points to one conclusion: the information in most classrooms is not presented in a way that corresponds to deaf students' learning styles.

In a K-12 mainstream environment, deaf students do not receive equal instruction in the classroom. A mainstream environment is when a deaf person is being placed among hearing peers in a classroom. Deaf students are provided with access services including

interpreting, c-print, and notetaking services to gain equal access to education in the classroom environment. With these services, Marschark stated that the students are receiving "mediated instruction" as opposed to direct instruction. Direct instruction means that information from an instructional source is presented directly to the audience without the use of an intermediary. A recent study by Marschark, Convertino, and LaRock has shown that deaf students typically lag behind their hearing peers in a mainstream environment despite equal accessibility in the classroom. The research results showed that deaf students have consistently lower scores than their hearing peers in comprehension tests of lecture content even when they are supplied with a highly qualified interpreter. (Marschark, Convertino, LaRock, 2004, in press.) Although this study was conducted in a K-12 classroom environment, it can be applicable to a college level environment like RIT which also incorporates a mainstream environment. This is not to say that access services are at fault, but that the success of direct instruction cannot be replicated even under optimal conditions. Therefore, the expectation that deaf students will comprehend or retrieve information equivalent to direct instruction especially in an instructor-led classroom would be imprudent.

Another disadvantage is that deaf students often are not able to fully comprehend abstract concepts taught in the programming courses at RIT. This is likely connected to relational versus item-specific processing. Two studies conducted by Marschark showed deaf students have a tendency toward item-specific processing rather than relational processing. Without understanding the relationships between concepts

taught in class and things they already understand from real world experiences, deaf students struggle more than their hearing peers. One of the studies conducted by Marschark, DeBeni, Cornoldi, and Polazzo asked both deaf and hearing peers of similar ages to recall contents of passages that they had read. The findings indicated that deaf adolescents were able to recall individual ideas equal to their hearing peers, but they scored significantly less when recalling the ideas in relationship to each other. (Marschark, 2002) Because deaf students tend to process item-specific ideas and concepts, they struggle in academic courses that require proficiency in relational processing. The suggestion here is that due to their lack of ability to identify relations between abstract concepts (e.g. objects and classes), this should be considered an area of concern that needs to be addressed especially in a programming course.

Typically, college courses introduce material in a sequential manner, where information builds upon previously learned material. This is called sequential learning and is another area where deaf students struggle. A study by Krakow and Hanson (1985) conducted a test comparing recall of serial information for both hearing and deaf participants. They found that deaf participants lagged significantly behind in the printed area. This shows a strong possibility that textbooks, which often present materials or concepts in sequential format, may prove to be a hindrance to some degree for deaf students. A supplemental tool with some type of media other than written documents would assist in improving the comprehension of sequential information for deaf students.

Another issue related to serial recall is sign-based coding versus speech-based coding for short term retention in working memory. As previously stated, the study by Krakow and Hanson (1985) concluded that deaf students lag behind their hearing peers in recalling printed sequential information. This is not to say that the working memory capacity is in question; only that sign and speech based coding are differentiated in efficiency of processing information. This is related to the fact that deaf people use both sign-based and speech-based coding in their working memory while hearing students and hard of hearing students use speech-based coding to store information that is serial. Sign-based coding has been shown to be less efficient in comparison to speech-based coding because "digit production is faster in speech than in sign, and the individual who use speech-based coding can fit more information into their time-limited articulatory loops than deaf individuals who use sign-based coding." (Ellis & Hennelley, 1980).

Lichetenstein (1998) suggested that the level of speech skills among deaf students determines whether they use sign-based coding and/or speech-based coding in working memory. Deaf students with better spoken language skills would be more likely to use speech-based coding solely rather than sign-based coding and speech-based coding used by deaf students with low to moderate spoken language skills. Fingerspelling in ASL, which is frequently used in programming concepts, is associated with sign-based coding; therefore deaf students are at a disadvantage.

A significant study was conducted by Harry Lang and Fred Dowaliby (1999) that showed the effect of adjunct aids as an instructional tool with deaf college students. They examined different impacts of various multimedia strategies by presenting content in different ways. The study revealed that students with various reading skills improved significantly after using the instructional tool. The average pretest scores (maximum of 11 points) for low, moderate, and high level deaf readers were 5.6, 7.5, and 8.2 respectively. After using the instructional tool with a combination of text reading, content video, sign video, and adjunct questions, the average posttest scores were 8.4, 10, and 10.4. By using the instructional tool, the participants with low reading skills were able to achieve slightly better scores than students who had not yet used the instructional tool (Lang, Dowaliby 1999).

When examining the adjunct aids individually, the study showed that adjunct questions were the most effective aid in the instructional tool for deaf participants with low and moderate reading skills. The combination of all the aforementioned adjunct aids also benefited students with high level of reading skills, leading them to achieve almost perfect scores on the tests conducted in the study. They benefited the most from the signed videos and the least from the adjunct questions (Lang, Dowaliby 1999). This shows there is a strong possibility that a combination of visual concepts along with adjunct questions and signed videos can boost scores for deaf students especially those who struggle with current course materials, which is usually text-based.

In conclusion, deaf students can achieve better grades and comprehension in programming courses with the aid of a learning tool. This can be accomplished by finding and creating the most effective tool to support their learning. Research has proven that a supplemental learning tool can benefit deaf students outside the classroom, but it has not been proven to promote academic success in programming courses. It addresses the need of a different approach without drastically changing the dynamics of the classroom. The learning tool should not be perceived as a "magic wand" to promote overall academic success. However, the goal of the learning tool is to promote comprehension of programming concepts by means of incorporating adjunct aids that includes a variety of visual elements. The purpose of the learning tool is to serve as an addition to current course materials that closely conform to their learning style.

Learning Tool Application

The learning tool program is a user-driven application designed for students to have virtually full control over their learning experience. This computer-based learning tool consists of four modules on decisions and advanced decisions in object-oriented programming, specifically Java. The modules have an average of 12 slides, not including the slides with multiple choice questions. The window size of the application is set at 1024 x 768.

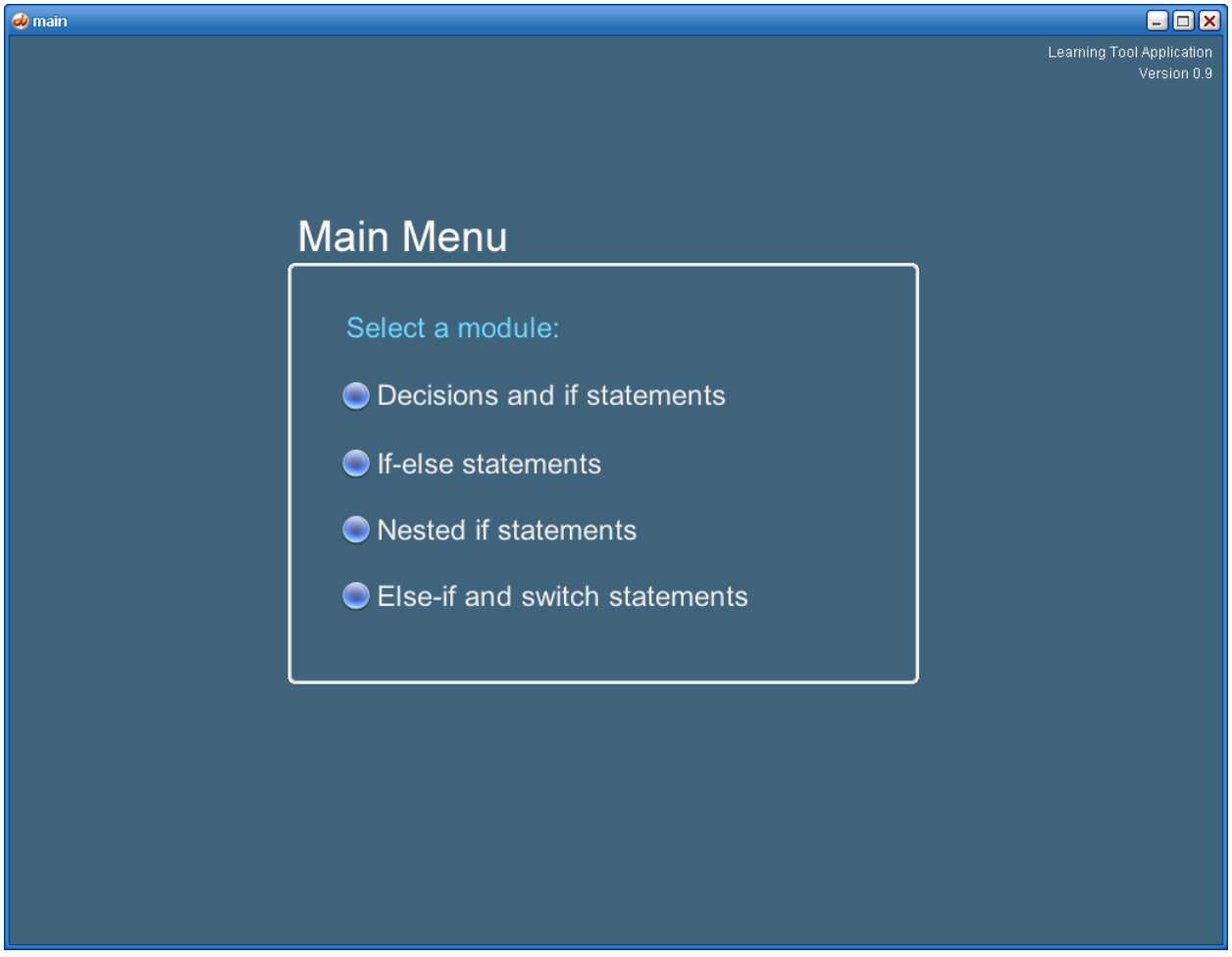

Figure 1: Main menu of the learning tool application

The application is automatically executed when the compact disc is inserted into the machine. The main menu (see Figure 1) lists the four different modules which are linked to four separate Director movies. Any of the modules will open in the same window. The main menu can be accessed at any time in each of the four modules by clicking on the icon with the house symbol.

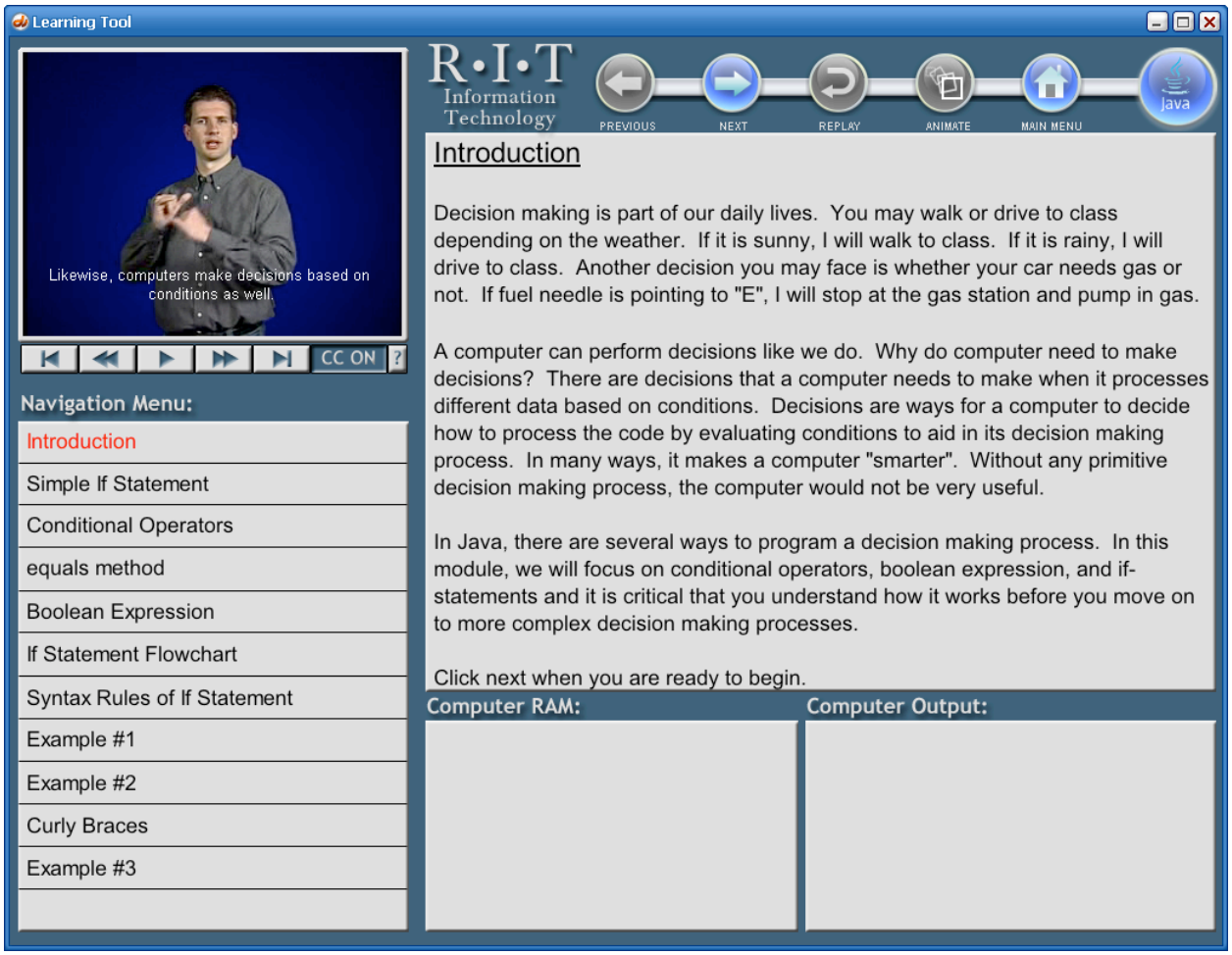

Figure 2: Introduction of "if statement" module

As you can see in Figure 2, most of the slides have a video clip located on the upper left of the screen that corresponds with the content in the main (largest) box. The duration of each video clip ranges from twenty seconds to two minutes. I am the presenter in the

video and the signs are English-like with American Sign Language. I discussed choice of signs with Joe Stanislow to find the best signs relevant to the concepts in object-oriented programming. Because the information technology field is relatively new, the deaf community has not established consistent signs for IT vocabulary.

The application is user-driven, which means that the user has full control of the pace by navigating the buttons. The options on the navigation bar are: previous, next, replay, animate, and main menu. The 'previous' button will go back one slide while the 'next' button will proceed to the next slide. The 'animate' button will begin an animation, which appears at certain points throughout each module. The only part of the application that cannot be controlled by the user is the pace of an animation. Because of that, the replay button was added as part of the navigation system to replay the animation.

The videos are controlled at the user's discretion. The videos are paused at the start of each slide and the participants can decide to watch it or not. Although the captions in the videos are on by default, the participants can also decide to turn off the closed caption in the videos. All of the videos are sized at 320 x 240 and they are positioned at the top left of the application. Because the videos incorporate sign language, all of the videos in the application run at 30 frames per seconds for maximum clarity.

Two of the four modules have an animated flowchart that exhibits how a program takes a different route based on a condition. As you can see in Figure 3, it will prompt the participants to select a condition and click on the animate button to see the flowchart in

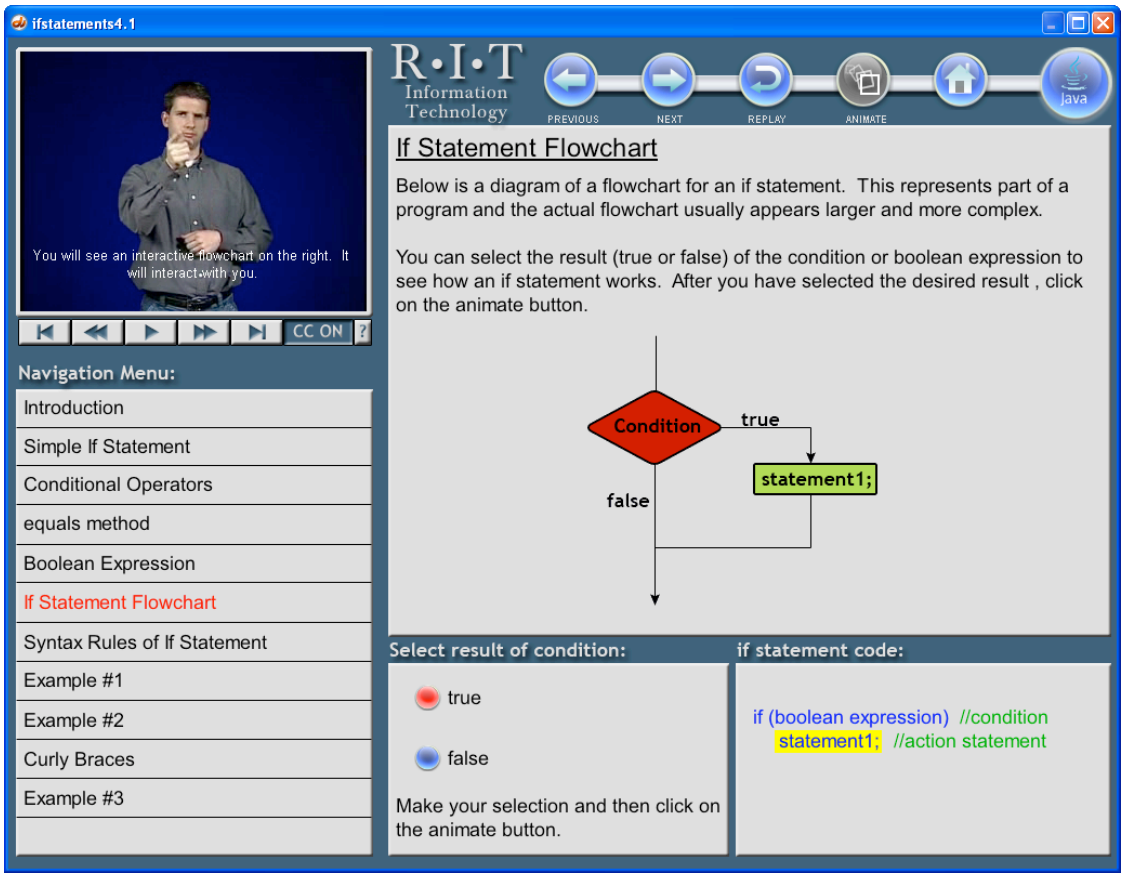

Figure 3: Animated flowchart in "if-statement" module

motion. While the flowchart is being animated, a part of the code is highlighted to show how it corresponds to the code.

Each module has animated examples with actual programming code that shows the participants how a program works. When a variable initialization takes place, the application shows the information of the variable in the "Computer RAM" panel. You can see that the information about variable "myAge" has appeared in that panel since

the animation has already done the variable initialization of "myAge". (see Figure 4)

The other panel, "Computer Output", represents what a person would see on a

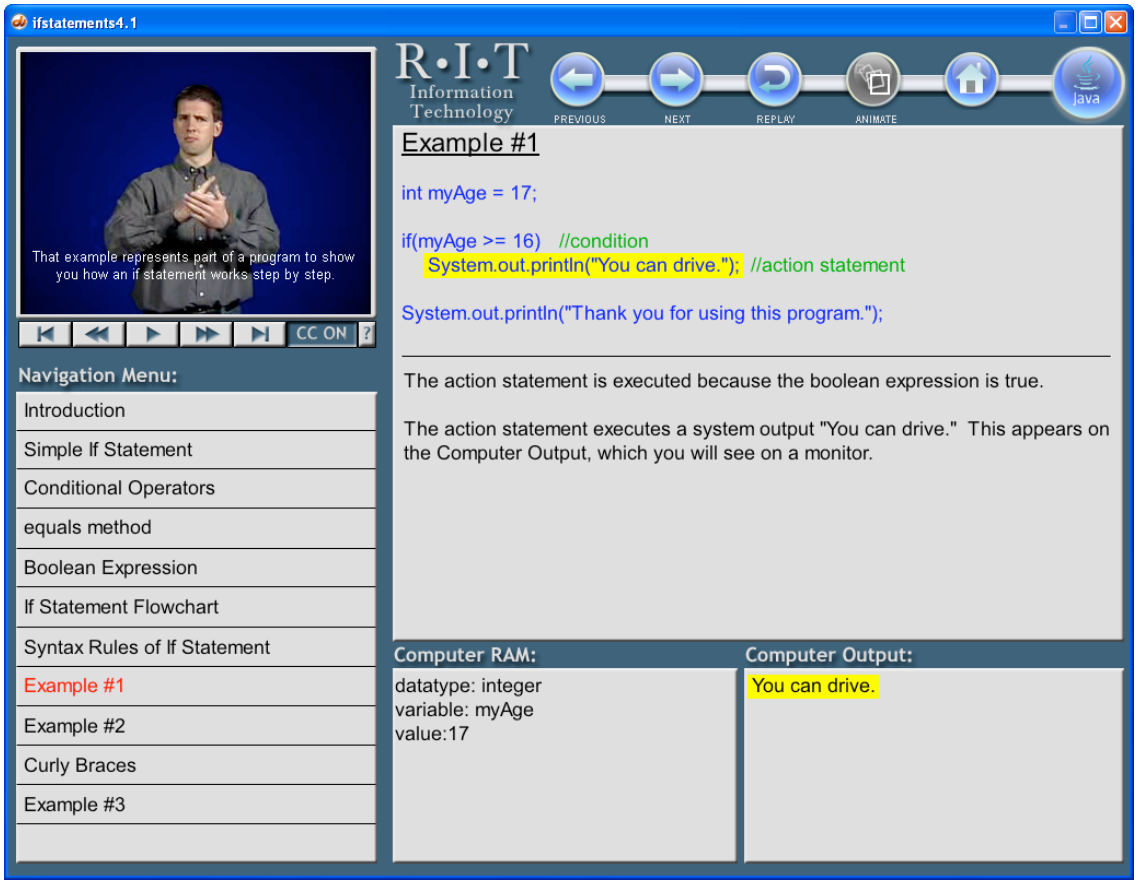

Figure 4: Animated example in "if statement" module.

computer monitor. When the animation encounters a system output, it will display the statement in that panel.

The aforementioned research studies by Lang and Dowaliby (1999) have shown that adjacent questions are vital to increasing knowledge and comprehension of content. For this reason, each module has several questions relevant to the content. All of the questions are in multiple-choice format. As you can see in Figure 5, participants can make their selection by clicking one of the buttons associated with the desired answer.

The application will immediately provide feedback based on their selection. When the participant selects the correct answer, the feedback will appear in green color along with a brief comment explaining why the selection is correct.

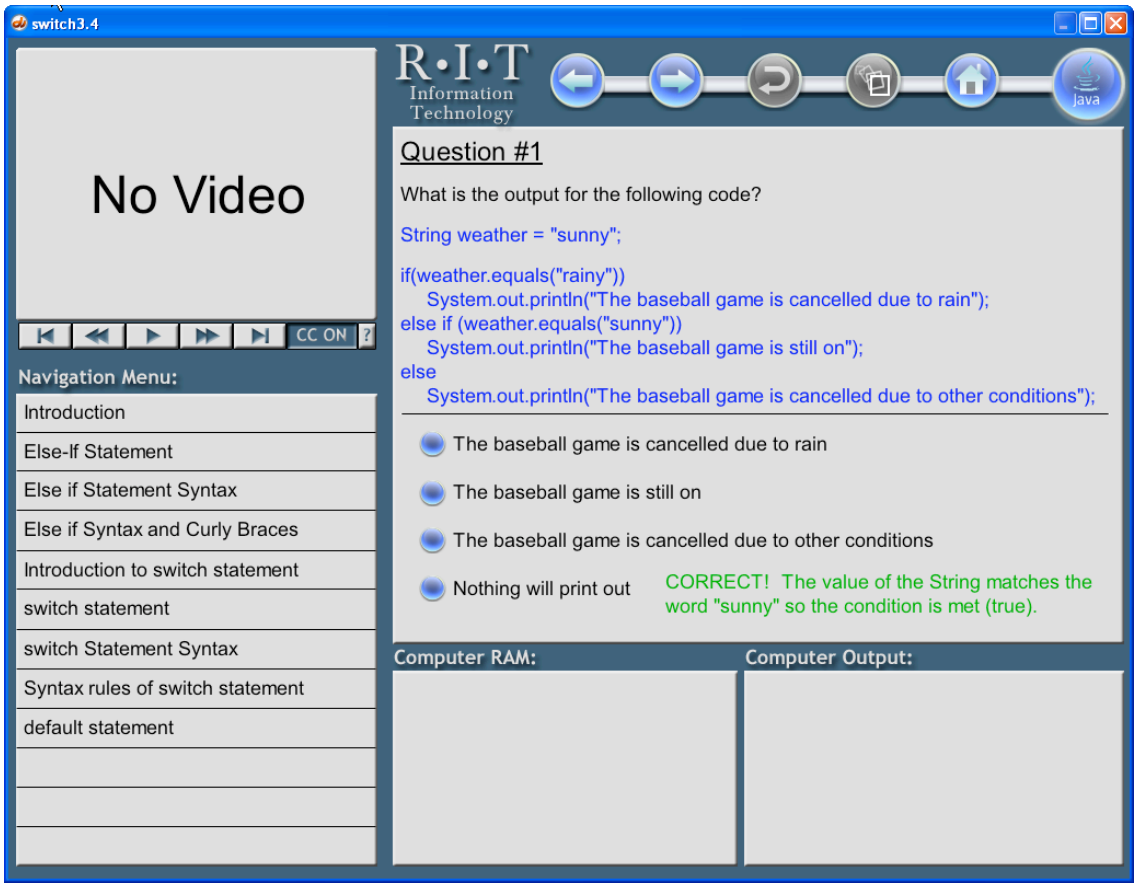

Figure 5: Multiple choice question in "else-if & switch statements" module.

An incorrect selection will have a red comment, and asks the participant to try again or review applicable content. To ensure a complete learning experience, the application does not allow the participants to continue to the next slide until a selection has been made.

At the end of each module, the learning tool application will inform the participant that they have reached the conclusion of that particular module. It will direct the participant onto the next module in sequence. This ensures that the participants learn in the same manner as they would in a classroom environment. The learning tool also encourages participants to review the materials as many times as they feel necessary.

Methodology

Based on previous studies, a learning tool can be used to help a deaf person understand specific programming concepts. Improving overall academic success of deaf students is beyond the scope of the learning tool. The learning tool application was developed in hopes that it can bridge the gap between hearing and deaf students. Therefore, a pilot study was taken to investigate the potential of the learning tool. This study was approved by the Institute Review Board. (see Appendix A)

Purpose of the Pilot Study

A pilot study was conducted to examine the effectiveness of the supplemental learning tool. Based on previous research, my expectation was that the learning tool would result in a substantial increase in comprehension of programming concepts. The students were evaluated based on their comprehension of specific concepts. The assessment compared comprehension learning from the classroom and learning from the supplemental learning tool. There were two separate testing sessions offered to accommodate the participants' schedule. The average duration for each session was two hours and 15 minutes. Both sessions were closely monitored by the principal investigator at all times.

Participants

There are 61 cross-registered deaf students currently registered for Information Technology courses. This number was reduced to 14 by eliminating students who have already passed course number 4002-217 (Programming for Information Technology I). A total of nine participants were recruited in exchange for free pizzas and sodas. Four of the nine participants have withdrawn from their programming courses (4002-217 or 4002-208).

Informed Consent Form

The participants in the study were required to read and sign an informed consent form (Appendix B). The informed consent form gives details about the purpose of the pilot study. The risks, benefits, and confidentiality of the study were also explicated in the form. The participants' signature confirms their agreement. In addition, the principal investigator of the study was required to bear witness with his signature.

Test #1

The participants were given a preliminary test (Appendix C) immediately after they signed the informed consent form. The primary purpose of the preliminary test is to evaluate their comprehension and knowledge of various concepts pertaining to decisions and advanced decisions in Java. The questions on the test were mostly multiple choice questions with two questions asking the participants to fill in the blank. There were 14 questions altogether. The questions pertain to concepts in the learning tool application. All of the participants have already been exposed to this information

in the classroom and from required textbooks. Feedback was not given to the participants during this test phase.

Learning Tool Application (Compact Disc)

After completing the first test, the participants were each given a copy of a compact disc that contained the learning tool application. They were advised to determine their own pace because there was no time limit. Explicit instruction were given to the participants to start with the "if statement" module and to follow the program's direction for subsequent modules. The participants were instructed not to talk to each other or ask for clarification of the lessons in the module.

Test #2

Upon completion of all four modules, the participants were administered a second test (Appendix D). The post test contained similar questions to the first test. The first five questions were rearranged and the rest of the questions were placed in the same order as the first one. Several of the questions are identical to the first test, but subtle changes were made to the value of a variable. Like the preliminary test, there were a total of 14 questions with 12 multiple-choice questions and two questions fill in the blank questions. This was to ensure that the level of difficulty of the preliminary test and post test remained as equal as possible. Feedback was not provided during this test phase.

Learning Tool Survey

After the participants completed the learning tool, they were asked to complete a survey about their experience with the learning tool application. The survey (Appendix E) contained nine questions that were measured on a Likert scale from 1 to 4. The scale was established deliberately to compel the participants to express an opinion rather than pick a neutral number. Four additional open-ended questions were included in the survey to collect comprehensive feedback. Those questions were designed to inquire about specific areas of the learning tool application. While those questions cannot be measured, the feedback is invaluable for possible revisions in the future.

Informal Inquiry – Post Session

When each of the participants had completed their tasks, an informal oral inquiry was conducted by asking general questions about their two-hour experience. Their responses were documented by the investigator.

Results

Preliminary Test Analyses

The test scores were assigned a value of 1 if the selection is correct and 0 if it is incorrect. The total score can range from a minimum of 0 to a maximum score of 14. The individual test scores for the preliminary test ranged from 4 to 11. The results for each individual are compiled in Figure 6. The mean score in the preliminary test is 7.55 with a standard deviation of 1.88.

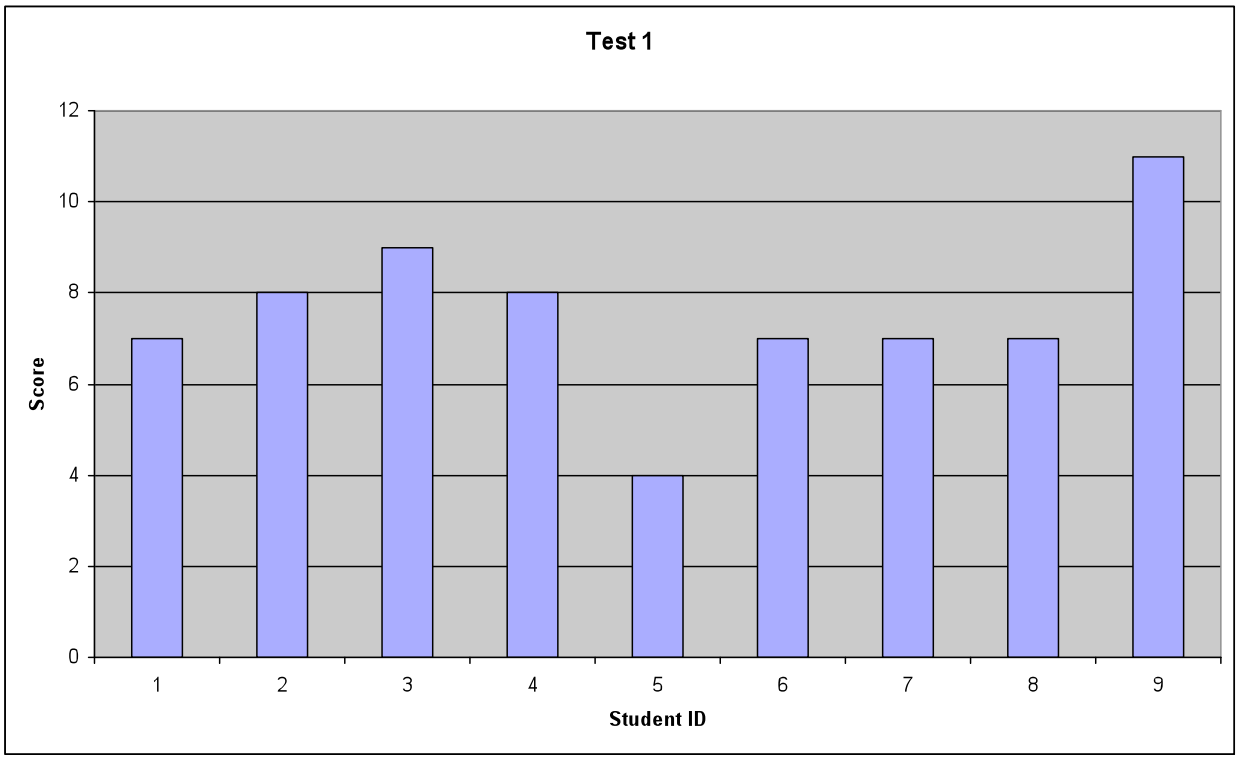

Figure 6: Scores of participants from the preliminary test.

The most frequent score among the nine participants is seven, which is half of the total score. It is noteworthy that one participant earned a passing grade (70 or better) on this preliminary test.

Post Test Analyses

The post test scores illustrate a different outcome in various ways. In Figure 7, the range of post test scores among the 9 participants is larger. The lowest score is two and the highest score is 12. It would be misleading to base the conclusion on the range of scores. The mean score in the post test is 9.89 with a standard deviation of 3.02.

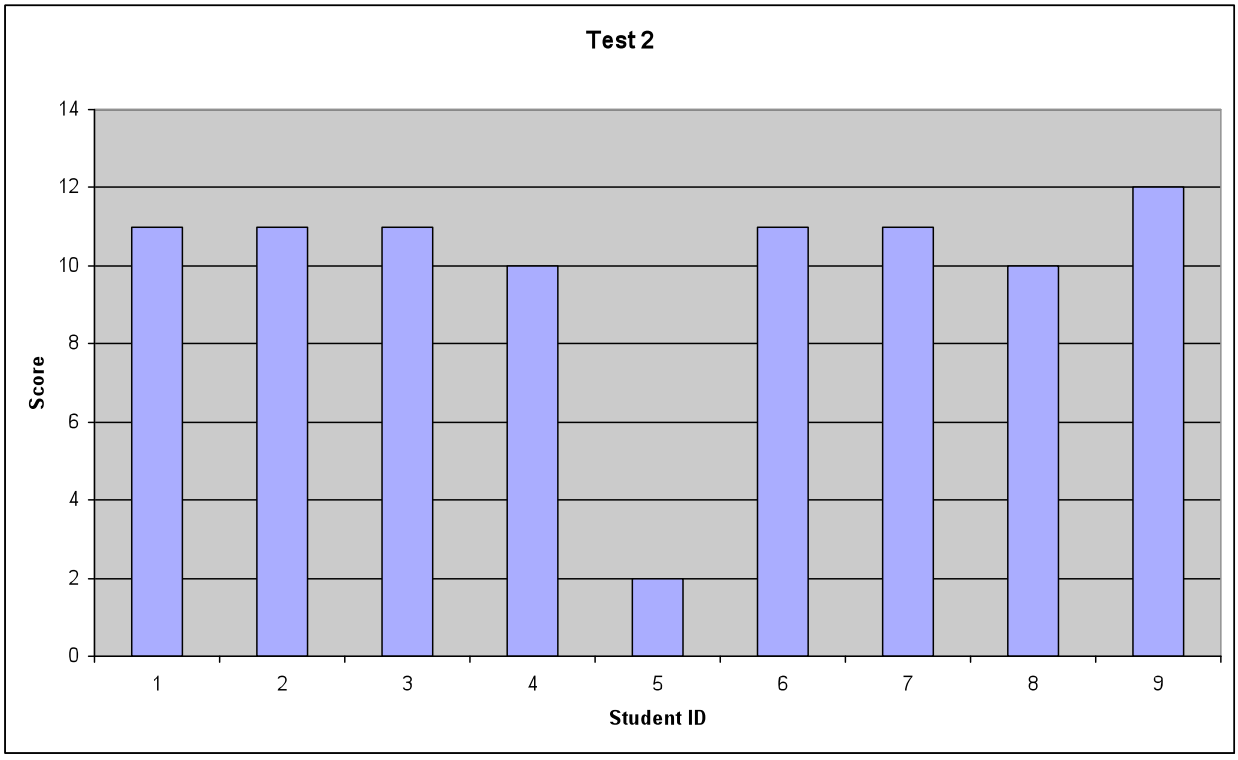

Figure 7: Scores of participants from the post test.

A score of 11 was the most recurrent among the participants in this test. Looking at the chart in Figure 6, it is apparent that the lowest score could be classified as an outlier. It is important to mention that the student with the lowest score spent the least amount of time (20 minutes) with the learning tool application compared to the average duration (75 minutes).

A comparison was performed between the preliminary and post test scores. The results are compiled in Figure 8 and indicate significant differences for the most part.

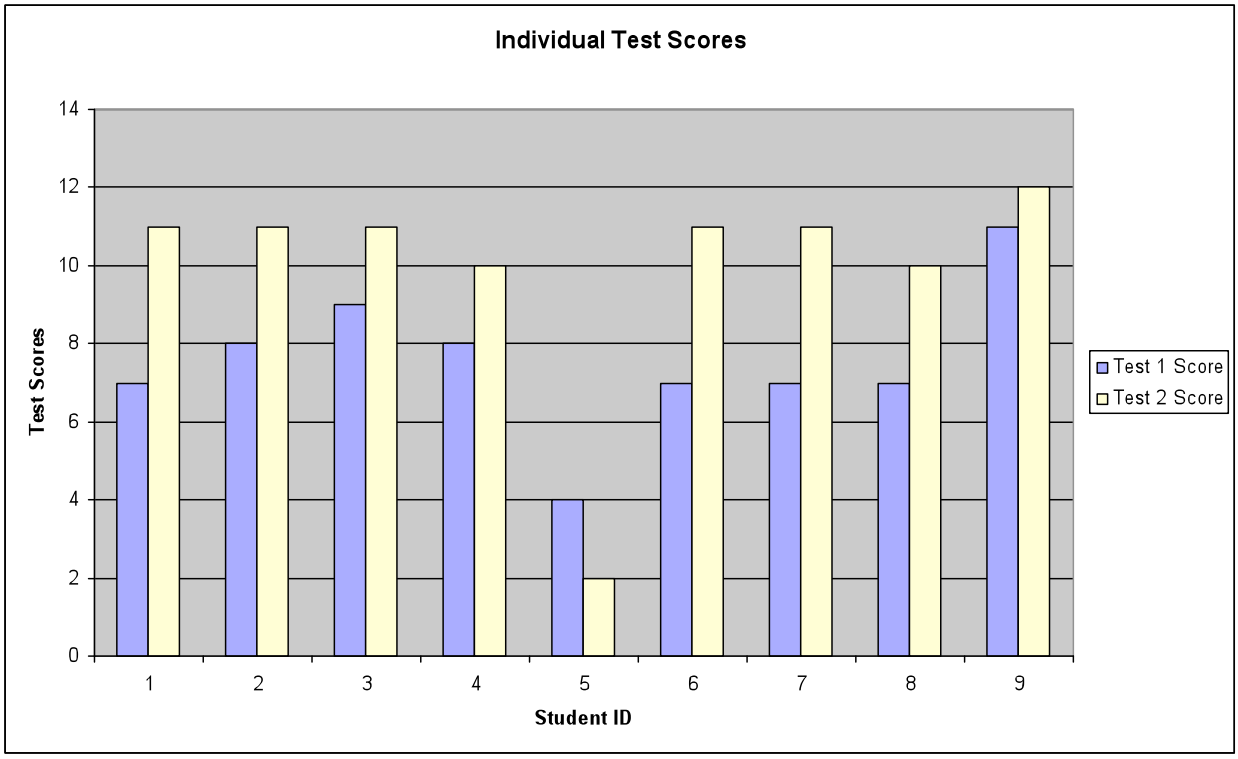

Figure 8: Comparison of preliminary and post test scores among participants.

It is important to notice that 8 out of 9 participants demonstrated an improvement in their test scores. The average increase in the test scores among participants is 2.33

points. The highest increase among the participants is four, which was also the most frequent increase. It is striking to note that 8 out of 9 participants earned a passing grade on the post test results.

Another comparison was performed to measure the average performance gap of the participants. In Figure 9, the average score measured by percentage for the preliminary test is 54 percent. The average score for the participants in the post test is 71 percent.

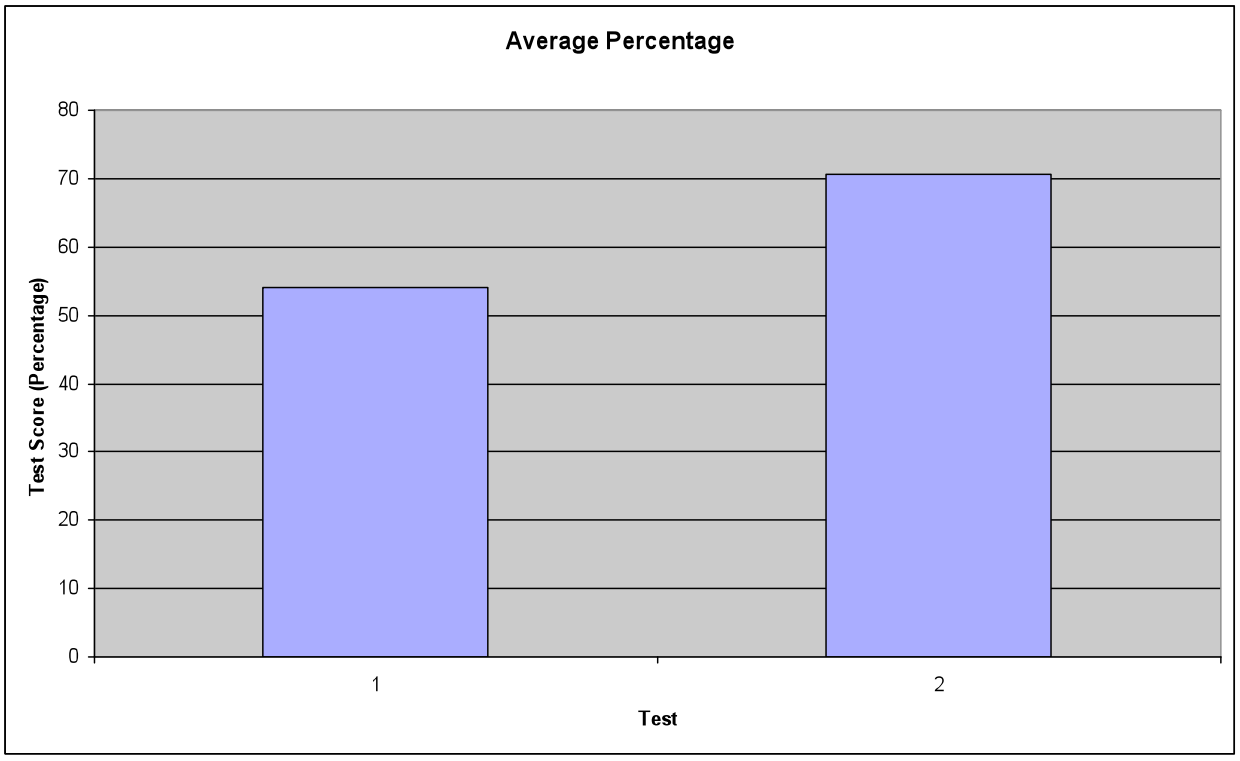

Figure 9: Comparison of average score (percentage-based) among participants.

This is a 17 percent increase from the preliminary to the post test scores. If the average were considered in a classroom, the whole group would have an average of a passing grade in the post test opposed to a failing grade in the preliminary test.

In summary, the current observation is a significant increase between the preliminary and post test results. Eight out of nine participants improved their test scores by an average of 2.33 points or 17 percent.

Survey Results

The first nine questions were rated in Likert scale format. The scale ranged from 1 to 4. The lowest value 1 indicates that the participants strongly disagree with a statement and the highest value 4 indicates that they strongly agree with the statement. All of the participants completed the learning tool survey. The chart in Figure 10 shows

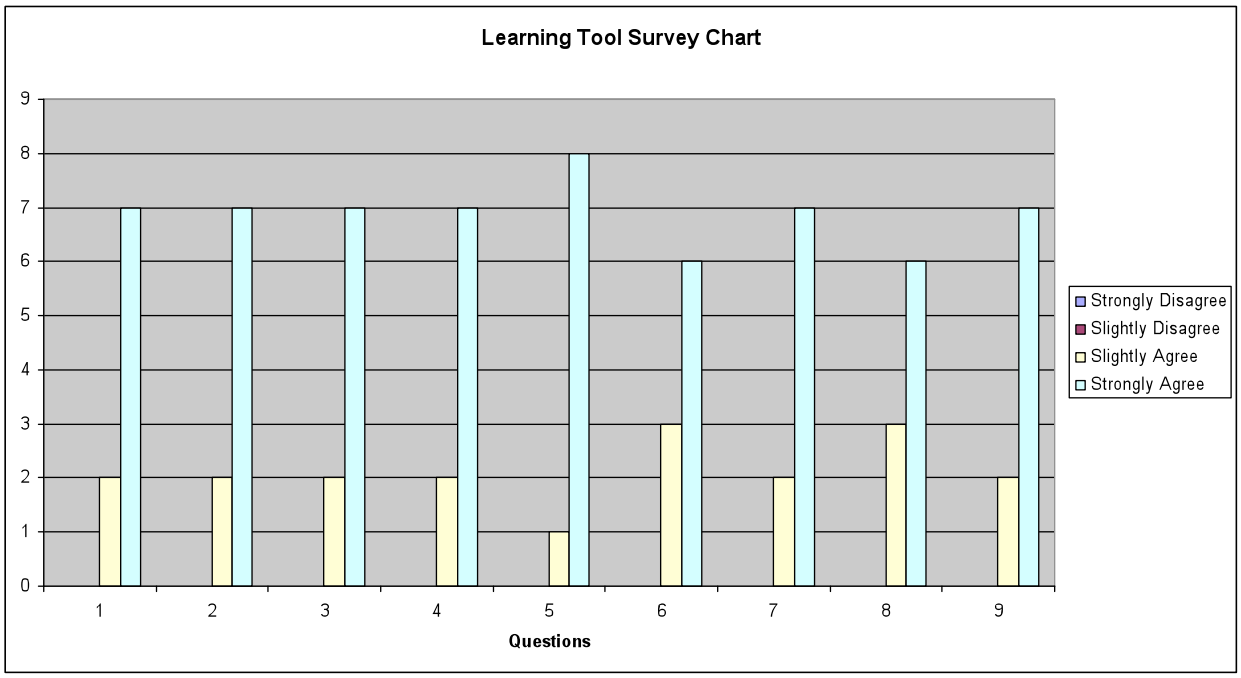

Figure 10: Compilation of data from first nine questions in survey.

the total number of selected responses for each question. It is interesting to point out that none of the questions were rated as 'Slightly Disagree' or 'Strongly Disagree'. This indicated that the learning tool was a positive experience for all of the participants.

The question that received the highest number of "Strongly Agree" rating was question number 5, "The examples helped me understand the concepts better". This proved that visual examples are highly valued by the participants.

	Strongly Disagree			Strongly Agree	
	1	2	3	4	Mean
Overall the program on the CD is an excellent learning tool.	0	0	2	7	3.777778
I am satisfied with the scope of information presented.	0	0	2	7	3.777778
I am satisfied with the quality of the content presented.	0	0	2	7	3.777778
I would prefer to use this tool in conjunction with the textbook.	0	0	2	7	3.777778
The examples helped me understand the concepts better.	0	0	1	8	3.888889
The questions helped reinforced what I just learned.	0	0	3	6	3.666667
The content clearly presented the concepts in Java.	0	0	2	7	3.777778
The videos in the program helped me understand the concepts better	0	0	3	6	3.666667
I would use this program again.	0	0	2	7	3.777778

Table 1: Data from learning tool survey.

As evidenced in table 1, the participants commended the learning tool and showed a high satisfaction rating overall.

There were four open ended questions on the survey that asked the participants to explain about their experiences with the learning tool. When asked about the most effective part of the learning tool, the responses were:

- By giving out true examples and providing students with multiple-choice questions
- Now I understand the part in switch statements and else-if statements better
- The animations allow you to understand visually how a program executes
- The animation part. I like to see an example of output in conjunction with the given statements.
- The part regarding animations was most effective I was able to see the actual process of applying the new concepts being taught.
- The questions as they reinforces what you just learned
- The videos because Brian's expressions and signing are more clear to understand
- A bilingual approach – ASL and English

The second questions asked the students about the least effective part of the CD. Their responses were:

- Slow loading time and some bugs were detected
- Could use more multiple choice questions
- The interface of the program was least effective due to bugs
- The animations were a little slow
- There were not enough lessons
- The animations ran too slow for a person who understands fast

The third question asked the student for improvements that could be made to enhance their experiences with the learning tool. Their responses were:

- Add more advanced coding
- The videos should run in conjunction with the animated examples and text statements
- Explain about the flowchart first
- I would like to see more animations of examples.
- Add a blank box of some kind for students to input and test out like syntax for example.
- Animation speed adjuster
- Allow it to run on both PCs and MACs

The final question asked the participants if they would recommend the learning tool to others. All of them responded positively. Some of their comments were:

- It would help to master Java effectively
- Definitely. It is very interactive and easy to follow. It allows you to be on your own pace and allows you to go back to where you want to reread something.
- Because it would help others understand better
- It helps improve visual understanding of more concepts
- I would recommend this CD to others because it is like a virtual classroom and the concepts presented by the CD was easy to grasp due to well-organized presentation
- It will help big time. A+++++

Overall, the participants agreed that the learning tool created a positive effect on their learning experience. The suggestion that they would use it again and recommend to other people showed the extent of their approval. To receive this type of positive

feedback is a step forward towards an atmosphere where deaf students are eager to learn. The suggestions for improvements were in regards to the participants' preferences. As stated earlier, I knew it would be virtually impossible to satisfy all of the participants in this area.

Conclusion

In search for the holy grail of a "level playing field" for deaf students, the learning tool application has created a positive impression. In the survey, the participants praised the learning tool and they demonstrated better scores on the post test as a result.

At this point, having seen the results from preliminary and post tests, the learning tool application illustrates that it can create a positive impact on deaf students. While the results are positive, it does not necessarily translate into immediate success for a full programming course. At this time, further investigation cannot be verified due to research constraints. However, the potential is there in the learning tool and further research is strongly recommended.

There are several variables that may have some effect upon the results. One is that the practice effect could be a factor in the participants' performance in the post test. Secondly, direct instruction appears to be a key factor in the students' overall comprehension of content specifically in programming. Lastly, the abundance of visual elements in the learning tool benefited deaf students and contributed to a better understanding of programming concepts.

Further research should include a second group of students to determine whether the practice effect has any bearing on the performance of students. This type of research is

warranted to ascertain the impact of the learning tool, if any on comprehension among deaf students in programming courses.