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Examining Audiology Students' Clinical Collaboration Skills When Using Virtual Audiology Cases Aided With No Collaboration, Live Collaboration, and Virtual Collaboration

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ABSTRACT

Introduction: The purpose of this study was to examine students' ability to use effective clinical collaboration online in a designed scaffolded environment. Three groups were formed to achieve this goal: two control groups (one using no collaboration and one using live, face-to-face collaboration) and one treatment group using virtual collaboration.
Method: A quasi-experimental design was conducted at two U.S. universities to examine whether there is a significant difference in clinical reasoning skills between three treatment groups using IUP Audiosim software. Two computer-based audiology case simulations were developed, and participants were randomly placed into the three groups. The clinical reasoning data were analyzed using one-way analysis of variance and Tukey's post hoc analyses.
Results: The results indicated that there was a significant difference in clinical reasoning skills between the three treatment groups. The score obtained by the no-collaboration group was significantly less than the scores obtained by the virtual and live collaboration groups.
Conclusions: The results imply that lower scores were associated with students receiving more instructor-designed content and higher scores with students receiving less instructor-designed content. Students who received more scaffolds with the collaborations may have demonstrated better decision-making outside the training exercise than those who did not receive scaffolds. However, lower scores on the exercise did not necessarily imply lower skill. Lower scores simply implied a different path toward mastery.

Research on clinical reasoning started in the 1970s, taking on a psychological perspective and exploring ways clinicians think when evaluating clinical cases (Pelaccia et al., 2011). Today's literature addresses the need to improve clinical reasoning through instructional design (Braun et al., 2019; Rencic et al., 2017). For example, Rencic et al. (2017) conducted a study to describe the clinical reasoning curricula at U.S. medical schools. They found that most of the medical students enter a clerkship or clinical training with only poor to fair knowledge of key clinical reasoning concepts, and they concluded that most medical institutions do not provide specific education for clinical reasoning (Rencic et al., 2017). The lack of available time, as well as the lack of expertise in teaching clinical reasoning, was identified as barriers for medical institutions' provision of clinical reasoning training (Rencic et al., 2017).

Clinical reasoning refers to the thinking and decision-making processes that are used in clinical practice. Higgs et al. (2008) have defined clinical reasoning as "a process in which the therapist, interacting with the patient and others (such as family members or others providing care) helps

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patients structure meaning, goals, and health management strategies based on clinical data, patient choices, and professional judgment and knowledge." Cognitive psychologists tried to understand the cause of clinical errors by analyzing the clinical reasoning process (Graber, 2005). Norman et al. (2017) identified the cause of errors in clinical reasoning among health care professionals and aimed to determine whether the error came from the System 1 heuristic process (rapid, automatic information gathering) or the System 2 analytical process of thinking (deliberate and conscious information gathering). The study found that health care professionals are vulnerable to commit mistakes in diagnosing cases due to three factors: cognitive bias, knowledge deficits, and dual process thinking (Norman et al., 2017). The negative effects created by cognitive bias, knowledge deficits, and dual process thinking can be lessened or fully eliminated with respect to making medical clinical diagnoses with the use and implementation of virtual patients. The use of virtual patients also has the benefit of decreasing barriers of time constraints and lack of expertise in teaching clinical reasoning.

Scaffolding is a process of guiding and assisting students throughout the learning process until those students reach specific goals. There are multiple types of scaffolding. The two main types are referred to as "hard" and "soft" scaffolds (Shin et al., 2017). Hard scaffolds are pre-scripted assistive tools, while soft scaffolds are dynamic, adaptive assistive tools that are given to a student throughout the learning process. Braun et al. (2019) reported on multiple forms of scaffolds used to improve clinical reasoning; one form includes representation prompts where students imagine the hospital setting and write how they can present the clinical case to their colleagues, and another form uses structured reflections whereby students are asked to reflect on their most-likely diagnoses (Braun et al., 2019).

This study was designed to examine students' ability to collaborate virtually on audiology cases. We examined the clinical reasoning skills and satisfaction levels of students using electronic virtual patients aided with no collaboration, virtual collaboration, or live collaboration. Therefore, a variety of scaffolding methods were used in the design of this study. While online simulations have been found to be essential in improving clinical reasoning skills, electronic virtual patients are still being evaluated and could be found to give improved results on the performance and satisfaction of students when aided with either virtual or live collaboration. This study attempted to add to the body of knowledge on these educational and training research topics in the field of medical/health care education. Therefore, this study was designed to examine student's ability to virtually collaborate on a clinical case and analyze the process of clinical reasoning but not the mastery or the final skill level. The study's goals were to determine if there are significant differences in terms of clinical reasoning skills between students using virtual patients aided without collaboration, aided with virtual collaboration, and aided with live collaboration.

Method

Participants

The participants in this study were a convenience sample of students in Audiology courses at a public university in Pennsylvania (University 1) and another public university in Kansas (University 2). Participants included 22 undergraduate students from University 1 and 16 graduate students from University 2. These 38 participants comprised two men and 36 women (consistent with the gender imbalances historically seen in Communication Sciences and Disorders programs and Audiology courses; Nemes, 2005). Participants' ages ranged from 18 to 34 years, with 84.6% of the students falling into the 18–24 year range and 12.8% falling into the 25–34 year range. All students had received previous coursework and training in audiometric evaluations and interpretation of audiometric testing.

Research Design

This study used a quasi-experimental design method to examine the clinical reasoning skills of the participants. Institutional review board approval was obtained from both universities. A power analysis was computed prior to the recruitment process using G*Power software (Faul et al., 2007). The sample size was calculated using G*Power software taking into consideration multiple parameters; power value that equals .9, effect size that equals .82, and a confidence level that equals 95%. The analysis determined that 24 participants would be needed to perform appropriate statistical analyses.

Audiology Simulation Program

For this study, a simulation program was developed using Adobe Animate as the leading software to design the interactions, Google Forms as a tool for scaffolding and problem-based activity, and WordPress as a web host for the simulation session. The simulation was online and in a 2D format. It was formed with an interactive simulation for the clinical tools used to diagnose the clinical cases, an interactive problem-solving activity in the form of branched questions with scenarios that change according to the choices chosen by the student, and a grading system that recorded the students' grades and saved them in an Excel spreadsheet.

For this experiment, two virtual cases were developed. The cases had identical steps and activities but were different in scenario and case design. Because students are different and have different knowledge and experience using computers and web tools, the first case was designed to be straightforward, which enabled students to know how to use the simulation and to bring all the students to the same point when dealing with the second case. The second case was designed to be more challenging, aiming to test the students' clinical reasoning skills.

The two modules designed for this experiment had the same process; however, the first module was a virtual case with an easy diagnosis and the second module was a virtual case with a more difficult diagnosis. "Easy diagnosis" in this situation meant the student received needed clues and was led to an accurate diagnosis with just simple reasoning. The case started with supplying the name, age, occupation, and medical history of the patient. From this information, the student was clued into a wide range of diagnoses. The simulation then presented questions to the student that provided continuous assistance throughout the reasoning process. This form of assistance is considered the hard scaffolding part of the case. The examination/investigation part of the module consisted of test results that were given to the student directly: The student just needed to look at the results and relate them to the case information initially given in order to reach a diagnosis.

The second module had the same process; the difference was in the complexity of the case. In this module, there were some indirect clues that forced the student to think carefully in order to reach the correct diagnosis. This second case started with a similar page of case information. However, the second case information had hidden clues that forced a student to pay attention in order to derive a correct diagnosis. In the experiment/investigation part, instead of giving the student the test results directly (as was done in the first module), the student entered an interactive simulation session. In this interactive session, the student received a simulation of the clinical devices used in an audiology clinic, such as the audiometer simulator.

Both cases started with a history-taking section. The history-taking section consisted of a problem-solving, multiple-choice set of questions (each worth 5 points) that enabled the student to obtain a patient's history and think about the possible differential diagnoses. During the problem-solving segment, hard scaffolds were embedded in the session in the form of scripted feedback. When the student got an answer wrong, a pop-up message appeared letting him/her know the answer was wrong. The pop-up message also indicated a reason why the answer was wrong and then asked the student to try again. Designing these hard scaffolds in this manner was meant to keep the student on track until a final diagnosis was obtained.

The second segment of the simulation was about examination and investigation. In this session, the student accessed a simulation of tests and devices used in diagnosing audiology cases, such as pure-tone air- and bone-conduction tests and tympanometry. This section of the simulation was different from the previous one. Here, the students used their clinical skills because they actively tested the hearing acuity and identified the hearing loss. This session was also supported by hard scaffolds in the form of pre-scripted test result pop-ups that allowed the students to know the correct examination results immediately after they completed the task. However, and as with the previous activity, any wrong answer was counted negatively in the overall grade for that student. This form of grading measured the clinical reasoning skills of the student and enabled the student to reach the end of the simulation.

The third segment of the simulation was another set of problem-solving multiple-choice questions, with hard scaffolds aimed to engage the student in a clinical reasoning process to diagnose the case based on the history and evaluation of the patient. The final question in this segment was a question about the final diagnosis of the case. Whether or not the student got the correct final diagnosis, customized feedback was given at the end with a detailed discussion about the case and how this final diagnosis was decided. The grades (points) were calculated automatically by the software, and the software automatically created a CSV file with the calculated data.

After finishing the first case, the program asked the student to proceed to the second case. At the conclusion of the second case, the student was asked to complete a satisfaction survey. The satisfaction of each student participant was measured using the Satisfaction Survey for Simulation Experiences, which was published in 2004 (Feingold et al., 2004). The reliability of the survey was previously established using Cronbach's alpha, and the reliability coefficient was .94 (Feingold et al., 2004; refer to Table 1). This survey was administered through Qualtrics and aimed to test the student's overall satisfaction with the simulation program and learning experience. Figures 1 through 4 provide examples of the case description and visual presentation seen by the participants.

Experimental Procedures

For the experiment, participants were separated into three groups at each university: 14 students in the no-collaboration group, 12 students in the virtual collaboration group, and 12 students in the live collaboration group. Each group contained scores from both undergraduate and graduate students since the data from both universities were combined. As mentioned previously, all students had received training in performing audiometric evaluations, but levels of knowledge using simulation cases was unknown to the investigators and likely varied from student to student. Each group of students had grade point averages that ranged between 3.25 and 3.98, which ensured the groups were equally capable and proficient at audiometric interpretation.

Table 1. Tukey's honestly significant difference post hoc for analysis of variance.

Dependent variable	(I) Three groups	(J) Three groups	Mean difference (I–J)	*SE*	Sig.	95% Confidence interval	
						Lower bound	Upper bound
Case 1 total	No collaboration	Virtual collaboration	−15.238*	3.491	.000	−23.78	−6.69
		Live collaboration	−19.821*	3.491	.000	−28.37	−11.28
	Virtual collaboration	No collaboration	15.238*	3.491	.000	6.69	23.78
		Live collaboration	−4.583	3.623	.424	−13.45	4.28
	Live collaboration	No collaboration	19.821*	3.491	.000	11.28	28.37
		Virtual collaboration	4.583	3.623	.424	−4.28	13.45
Case 2 total	No collaboration	Virtual collaboration	−16.964*	4.805	.003	−28.72	−5.20
		Live collaboration	−17.798*	4.805	.002	−29.56	−6.04
	Virtual collaboration	No collaboration	16.964*	4.805	.003	5.20	28.72
		Live collaboration	−.833	4.987	.985	−13.04	11.37
	Live collaboration	No collaboration	17.798*	4.805	.002	6.04	29.56
		Virtual collaboration	.833	4.987	.985	−11.37	13.04
Total	No collaboration	Virtual collaboration	−32.202*	7.403	.000	−50.32	−14.08
		Live collaboration	−37.619*	7.403	.000	−55.74	−19.50
	Virtual collaboration	No collaboration	32.202*	7.403	.000	14.08	50.32
		Live collaboration	−5.417	7.683	.762	−24.22	13.38
	Live collaboration	No collaboration	37.619*	7.403	.000	19.50	55.74
		Virtual collaboration	5.417	7.683	.762	−13.38	24.22

Note. Sig. = significance.
*The mean difference is significant at the .05 level.

The first group was the control group, and it was provided with the virtual cases with no collaboration. Members of this group were not allowed to talk to each other, and students were required to solve the cases independently. The second group of participants was given the same two virtual cases; however, this group was aided with live collaboration. This meant they were allowed to talk to each other and collaboratively solve the cases through live, in-lab discussions. The third group of participants was also given the same virtual cases; however, this group was aided with a virtual synchronous collaboration tool in the form of a chatroom. Therefore, the students did not talk to each other, but wrote to each other in a chatroom that enabled the students to collaborate virtually while solving the cases.

There was no time limit to complete the cases; however, all students completed the cases within 45 min. There was a volunteer proctor in each group to make sure the experiment was completed as planned. Proctors of the live collaboration groups were asked to make sure the live

Figure 1. History-taking section: first screen.

Figure 2. History-taking section: second screen.

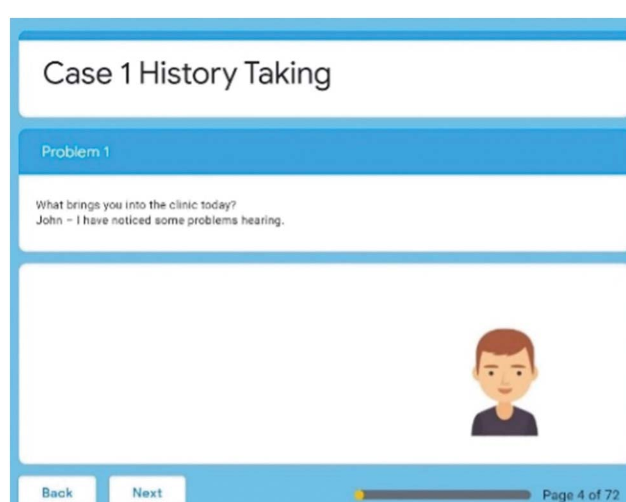
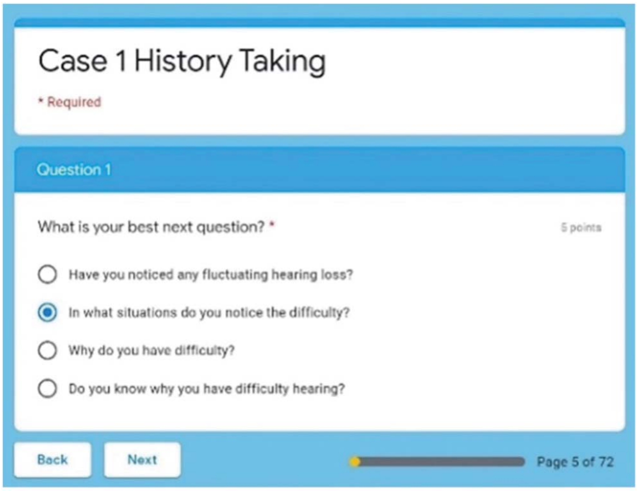


Figure 3. Screenshots of the history-taking session.

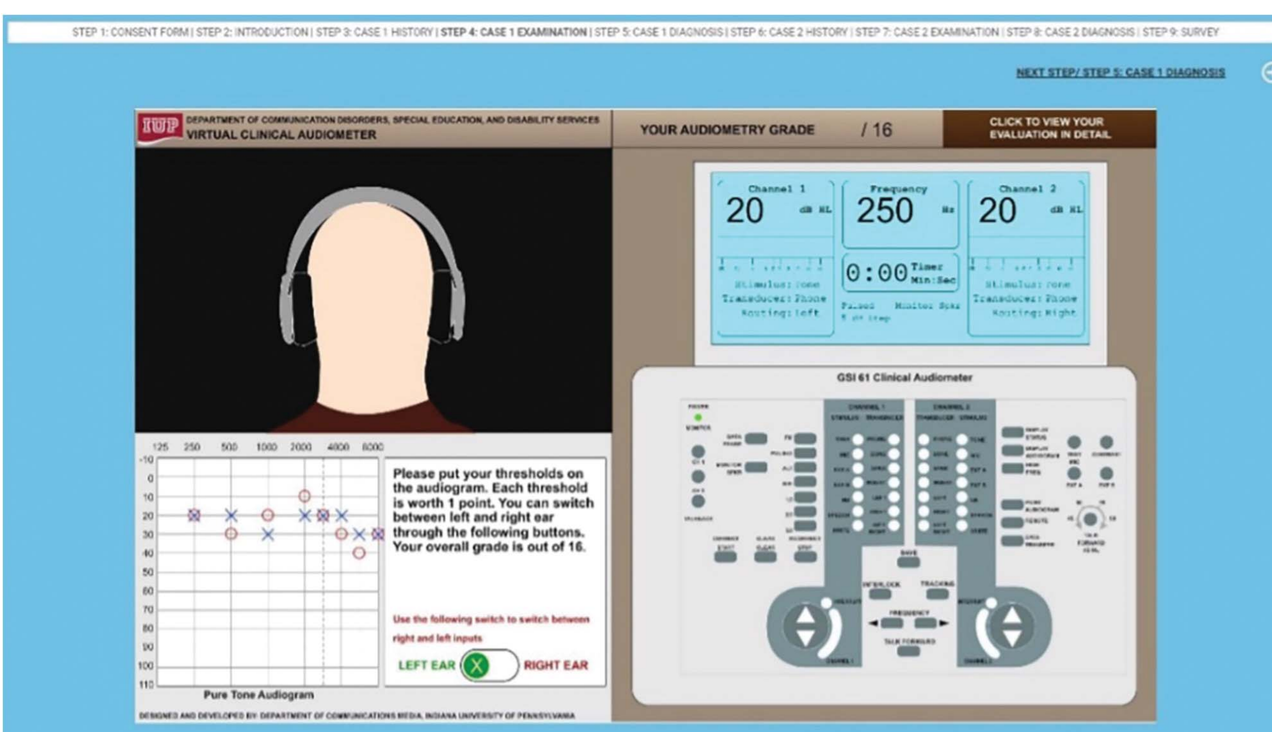


collaboration happened. Proctors made sure all students participated in the live collaboration activity and informed the students that the collaboration was mandatory for the activity.

For the virtual collaboration groups, the first author was monitoring the chat system and was asking students to collaborate virtually. The first author informed students that the virtual collaboration was mandatory for this activity. The activity was monitored, and the author made sure all students participated in the virtual collaboration activity.

Because there were three groups for this experiment, three versions of this simulation program were developed using the same two cases. The first version was a placebo. This placebo version was given to the control group, and it did not have any collaboration tools. The students in the control group solved the two cases individually and were not allowed to collaborate with others in the group. The programs were designed so that points were accumulated at every step of the simulation, and at the end of the session, the points were added up, and a final score was assigned to each student. The second version of the simulation program was the aided with live collaboration version. In this version, students were given the same version of the simulation that did not have a collaboration tool. However, these students were allowed to talk to each other in the lab and were able to collaborate in person with their classmates to solve the cases. The third version of the program was the one with virtual collaboration. In this version, the same simulation program was used, but virtual collaboration tools in the form of a chatroom and file-sharing tools were embedded in the program. In this third version of the simulation, students were instructed to collaborate via the online collaboration tools embedded in the program. The use of no-collaboration, in-person collaboration, and virtual collaboration models in this study

Figure 4. Audiogram simulation session.



was designed to ensure that the social interactions and collaborations with classmates met the requirements of several learning theories (situated learning theory, social development theory, and collaborative learning). The addition of hard scaffolding and soft scaffolding techniques (e.g., step-by-step directions and pop-up feedback) throughout the cases were meant to address best practices regarding major learning approaches important to clinical reasoning skills.

The progress of each student was recorded within the simulation program. Each segment was graded separately but was linked to the student's e-mail address. The e-mail address was used as an identifier, so the researcher could link all students' grades in all sections when the data collection began. After assigning the grade to each student's e-mail address, the e-mail address was deleted to destroy any identifiable information about the participants in this study.

The clinical reasoning skills of all three groups of participants were determined through analyzing the scores resulting from the virtual cases. Since two universities were included in this study, each university's students were divided into three groups. The data from each group in University 1 were added to the data from the corresponding group in University 2.

These computer simulations "graded" students and provided an overall score to represent their performance. The grades included detailed commentary for each section of the simulation and was designed to provide feedback to the student (refer to Figure 5). Lastly, the Satisfaction Survey for Simulation Experiences was completed by each student to obtain information regarding the student's experience with the simulation activity. Therefore, two forms of evaluation were incorporated in the simulation activity: a formative evaluation in the form of progressive feedback for each step a student went through, and a summative evaluation in the form of a total score for the simulation activity.

Results

The "no collaboration" group consisted of 14 participants and had a mean score of 83.93 out of 105 (80%) in Case 1, 69.29 out of 90 (77%) in Case 2, and a total of 153.21 out of 195 (78.6%). The "virtual collaboration" group consisted of 12 subjects and had a mean score of 99.17 out of 105 (94.4%) in Case 1, 86.25 out of 90 (95.8%) in Case 2, and a total of 185.42 out of 195 (95.1%). The "live collaboration" group consisted of 12 subjects and had a mean score of 103.75 out of 105 (98.8%) in Case 1, 87.08 out of 90 (96.8%) in Case 2, and a total of 190.83 out of 195 (97.9%; refer to Table 2).

An analysis of variance (ANOVA) test (one-way ANOVA) was used to answer the research question. The results showed that for Case 1, the F value was 18.05 and the p value was .000, which was significant ($p < .05$). Therefore,

Figure 5. Screenshots of the examination session.

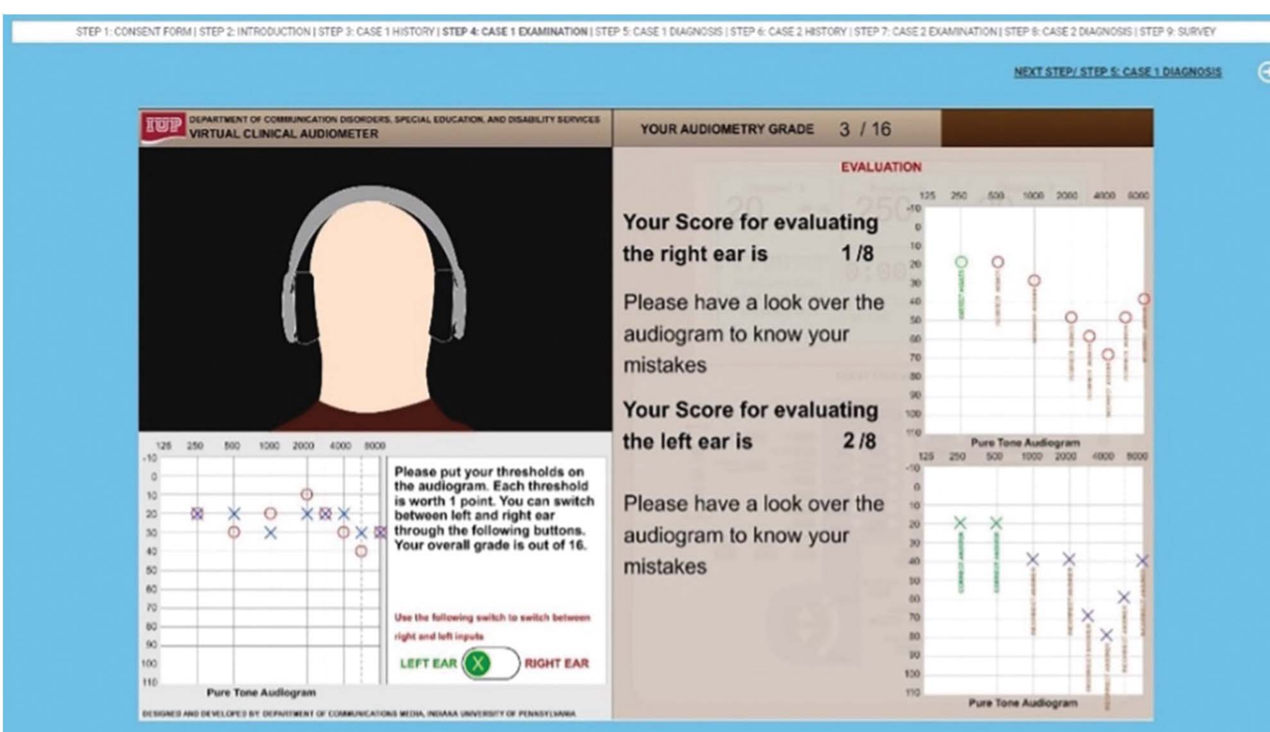


Table 2. Satisfaction survey for simulation experiences.

1. The virtual case used with the audiology simulation mimicked real-life practice.
2. The scenario adequately tested technical skills.
3. The scenario adequately tested clinical decision-making.
4. I was prepared for using the audiology simulation.
5. Audiology simulation needed an orientation to work with easily.
6. The patient simulator model provided a realistic patient simulation.
7. My confidence to practice in real life has increased.
8. I had a good learning experience using this simulation.
9. My clinical competence has been improved when I used this simulation.
10. This simulation prepared me to perform in the "real-life" clinical setting.
11. Throughout the simulation, I got continuous feedback that helped me perform better.
12. The teaching methods used in this simulation were helpful.
13. This simulation provided me with a variety of activities that promoted my learning of the audiology curriculum.
14. Overall, this simulation experience enhanced my learning.

there was a statistically significant difference in terms of clinical reasoning skills between participants using virtual patients aided with no collaboration, live collaboration, and virtual collaboration for the first case (refer to Table 3).

For Case 2, the F value was 8.97 and the p value was .001, which was also significant ($p < .05$). Therefore, there was a statistically significant difference in terms of clinical reasoning skills between subjects using virtual patients aided with no collaboration, live collaboration, and virtual collaboration for the second case (refer to Table 3).

When the two cases were summed and a total score was obtained, the F value was 15.46 and the p value was .000. Again, these results were less than .05, thus significant. Therefore, there was a statistically significant difference in terms of clinical reasoning skills between subjects using virtual patients aided with no collaboration, live collaboration, and virtual collaboration for the total of the two cases (refer to Table 3). The reason both cases were summed during the analysis process was to provide a new perspective to our data. That is, summing of data was used to determine if students—whether or not they were knowledgeable with the simulation software—benefit from embedding collaboration into a simulation activity.

No Collaboration Versus Virtual Collaboration

In order to investigate differences between the three groups and provide a more in-depth understanding of these results, post hoc analyses using the Tukey's honestly significant difference (HSD) test were performed. For Case 1, the no-collaboration treatment group's clinical reasoning score was 15.24 lower than the clinical reasoning score of the virtual collaboration treatment group, and this difference was statistically significant (p = .000). For Case 2, the no-collaboration treatment group's clinical reasoning score was 16.96 lower than the clinical reasoning score of the virtual collaboration treatment group, and this difference was statistically significant (p = .003). For the overall simulation, the no-collaboration treatment group's clinical reasoning score was 32.20 lower than the clinical reasoning score of the virtual collaboration treatment group, making this difference statistically significant (p = .000; refer to Table 3).

No Collaboration Versus Live Collaboration

For Case 1, the no-collaboration treatment group's clinical reasoning score was 19.82 lower than the clinical reasoning score of the live collaboration treatment group, and this difference was statistically significant (p = .000). For Case 2, the no-collaboration treatment group's clinical reasoning score was 17.80 less than the clinical reasoning score of the live collaboration treatment group, and this difference was statistically significant (p = .002). For the overall simulation, the no-collaboration treatment group's clinical reasoning score was 37.62 less than the clinical reasoning score of the live collaboration treatment

Table 3. Descriptive statistics for the three treatment groups.

						95% Confidence interval for mean			
Variable	Treatment group	*N*	*M*	*SD*	*SE*	Lower bound	Upper bound	Minimum	Maximum
Case 1 total	No collaboration	14	83.93	12.887	3.444	76.49	91.37	65	105
	Virtual collaboration	12	99.17	6.686	1.930	94.92	103.41	90	105
	Live collaboration	12	103.75	3.108	.897	101.78	105.72	95	105
Case 2 total	No collaboration	14	69.29	17.744	4.742	59.04	79.53	25	90
	Virtual collaboration	12	86.25	5.276	1.523	82.90	89.60	75	90
	Live collaboration	12	87.08	8.649	2.497	81.59	92.58	60	90
Total	No collaboration	14	153.21	27.777	7.424	137.18	169.25	95	195
	Virtual collaboration	12	185.42	8.908	2.572	179.76	191.08	175	195
	Live collaboration	12	190.83	11.645	3.362	183.43	198.23	155	195

Table 4. One-way analysis of variance for the three treatment groups.

Variable	Group	Sum of squares	*df*	Mean square	*F*	Sig.
Case 1 total	Between groups	2843.155	2	1421.577	18.048	.000
	Within groups	2756.845	35	78.767		
	Total	5600.000	37			
Case 2 total	Between groups	2675.345	2	1337.672	8.966	.001
	Within groups	5222.024	35	149.201		
	Total	7897.368	37			
Total	Between groups	10952.428	2	5476.214	15.463	.000
	Within groups	12394.940	35	354.141		
	Total	23347.368	37			

Note. Sig. = significance.

group and this difference was statistically significant (p = .000; refer to Table 3).

Virtual Collaboration Versus Live Collaboration

For Case 1, the virtual collaboration treatment group's clinical reasoning score was 4.58 less than the clinical reasoning score of the live collaboration treatment group, but this difference was not statistically significant (p = .424; refer to Table 4). For Case 2, the virtual collaboration treatment group's clinical reasoning score was 0.83 less than the clinical reasoning score of the live collaboration treatment group, but this difference was also not statistically significant (p = .985; refer to Table 4). For the overall simulation, the virtual collaboration treatment group's clinical reasoning score was 5.42 less than the clinical reasoning score of the live collaboration treatment group, and as with the other results, this difference was not statistically significant (p = .762; refer to Table 4).

Experiment-wise error was calculated to predict the probability that one or more of the significant tests results in a Type I error. It was determined that the experiment-wise error was less than .0001.

Overall Satisfaction With Simulation Experience

To get insight into the students' level of satisfaction, a one-sample t test was conducted on the satisfaction survey data to determine whether students were satisfied or dissatisfied with the simulation experience. The results showed that 11 out of 14 questions had statistically significant results (refer to Table 5). The test value for the one-sample t test was 2.5, and this mean was lower than the neutral point ("3") of the Likert scale. Because lower points mean more satisfaction, this test result highlighted that there was significant satisfaction with the simulation experience. Stated differently, directionality of the Likert score was portrayed with negative numbers denoting higher satisfaction and positive numbers denoting lower satisfaction. A mean score of "−1" denotes the highest satisfaction, while a "+1" denotes the lowest satisfaction. Table 5 displays the survey items that were statistically significant, including the values that determines the direction of this satisfaction. The survey items with nonsignificant results included the following: "The audiology simulation needed an orientation to work with easily," "My confidence to practice in real life has increased," and "The simulation prepared me to perform in the real-life clinical setting."

Discussion

When running a one-way ANOVA on the performance scores of the audiology simulation, there was a significant difference between the three treatment groups. Post hoc Tukey's HSD tests for ANOVA indicated significant differences between the no-collaboration and virtual

Table 5. Survey items and t-test scores resulting from the *Satisfaction Survey for Simulation Experiences* (Feingold et al., 2004) used to determine whether students were satisfied or dissatisfied with this simulation experience.

Statement on survey	t-test score
The virtual case used with the audiology simulation mimicked real-life practice.	−1.0
The scenario adequately tested technical skills.	−0.84
The scenario adequately tested clinical decision-making.	−0.97
I was prepared for using the audiology simulation.	−0.40
The patient simulation provided realistic patient simulation.	−0.72
I had a good learning experience using this simulation.	−0.61
My clinical competence has been improved when I used this simulation.	−0.42
Throughout the simulation, I got continuous feedback that helped me perform better.	−0.53
Overall, the simulation experience enhanced my learning.	−0.45
The teaching methods used in this simulation were helpful.	−0.61
The simulation provided me with a variety of activities that promoted my learning.	−0.84

collaboration groups, and the no-collaboration and live collaboration groups. However, there was no significant difference between the virtual collaboration groups and live collaboration groups.

During the simulation experience, two treatment groups were asked to engage in a collaborative reasoning experience through virtual or live social interaction. As mentioned previously, the main total score of the no-collaboration treatment group was 153.21 points, which was significantly less than both the virtual collaboration group (185.42 points) and the live collaboration group (190.83 points). The only difference between the no-collaboration simulation and the virtual/live collaboration simulation was social interaction. This difference confirms that social interaction had a significant effect on these audiology students' performance. While the main live collaboration score seems to be slightly higher than the main virtual collaboration score, there was no significant difference between the two treatments. This finding reveals that social interaction itself has a significant effect on performance no matter how this social interaction is experienced (live or virtual). These audiology students embraced collaborative roles to actively learn and succeed in understanding the cases presented when placed in the virtual and live collaboration groups.

Collaboration is considered a soft scaffold (Pérez-Sanagustín et al., 2015). The soft scaffold is dynamic, customizable, and changeable according to the user's input (Gonulal & Loewen, 2018). Collaboration is a good application of soft scaffolding, where peers act as units in this scaffolding process (Lu et al., 2010). Considering the clinical reasoning process is an organized step-by-step process and not a holistic one, scaffolding can be used effectively to support clinical reasoning (Pérez-Sanagustín et al., 2015). That is what appears to have happened in this experiment. During this simulation experience, the two treatment groups were put into a collaborative learning environment and asked to solve each step of two virtual cases to make sure the collaboration was used as a scaffolding approach.

Since this study did not include a post-intervention measure, the scores achieved during the training are indicative of student's clinical reasoning process but not the mastery or the final skill level. Thus, we can assume that embedded scaffolds in the simulation program helped students to demonstrate better clinical reasoning processes outside the training exercise. The results would imply that lower scores were associated with students receiving more instructor-designed content and higher scores with students receiving less. However, lower scores on the simulation do not necessarily imply lower skill, just a different path toward mastery.

Implications

Collaboration creates an active environment where students interact to perform group reasoning (Lu et al., 2010). This collaborative reasoning reduces the intrinsic cognitive load, which, in turn, enhances the learning experience (Norman et al., 2017). Collaborative reasoning is also found to be more effective than individual reasoning then dealing with clinical cases (Bateman et al., 2012). Similarly, scaffolding explains how social interaction can positively affect learning outcomes. Xun and Land (2004) proposed a conceptual framework to scaffold problem-solving activities using prompts and peer interactions, which is a similar framework to the design of the simulation experience used in this study. Therefore, various theories of learning can explain how these different processes of collaboration (virtual and live) were effective in enhancing the audiology students' performance, and these results can be explained through theories of situated learning and social development, as well as scaffolding and collaborative learning. The findings from this study have the potential to give insight into the efficacy of virtual collaboration and assist with designing new virtual patient models.

The findings of this study have implications for the use of online collaboration and shows that online collaboration is effective for students' clinical reasoning processes. These findings also imply that collaboration in the two forms used in this study is not impacted significantly by the process used to provide the collaboration. That is, having colleagues close by to collaborate with in person is essentially the same as collaborating with colleagues virtually. These results suggest that collaboration is important to the learning process and should be fully developed in multiple educational settings within audiology training programs. That is, it appears that learning can be enhanced when collaboration between the classroom instructor and students are done in an in-person or even a virtual mode. At a higher level in the training process, learning can also be enhanced when collaboration between the preceptor and students occurs in a clinical setting. It appears that having peer–collaborators present, whether in-person or virtually, can help a student improve the learning experience. These findings could support the use of third-year audiology graduate student providing clinical services at the same time a second- and/or first-year audiology graduate student is providing services so that discussion and collaboration on diagnoses and treatment options can take place. In fact, now that instructors and students have gained experience with online video-conferencing platforms (e.g., Zoom, Google Hangouts, Skype) throughout the COVID pandemic, collaboration during clinical practica should routinely take place for increasing clinical reasoning skills in these allied health profession educational models. In many ways, this is similar to a "real-world" scenario in which multidisciplinary team members collaborate on a case in order to provide the best services available to patients.

Limitations and Future Directions

As with any study, this study has limitations with respect to design and interpretation. For example, audiology virtual patients were the target simulation for this study and, therefore, findings from this study cannot be generalized to cover other health care specialties. However, this study could be replicated for future research to examine the effect of collaboration on clinical reasoning skills in other specialties.

The design of this study did not allow the investigators to evaluate the learning theory models using other widely practiced methods of student learning and clinical reasoning. For example, it is not known how the use of collaboration with simulated cases measures up when compared to open- versus closed-book examination processes, and it is not known how simulated case collaboration measures up to interprofessional practice education models for clinical reasoning education.

This study, due to the COVID-19 pandemic, could not be designed to include a post-intervention measure. Thus, results do not reflect on student's mastery, but they describe and analyze the clinical reasoning processes of the student. A future study is needed to test the effect of the collaboration on student's mastery skills.

The role of collaborative reasoning in overcoming clinical errors is still needed, and future studies must address concerns related to determining how the collaboration process affects lower performing students. That is, with collaboration, there is always a fear that the highest performing student will carry the group and some students will be left behind if they fail to participate or speak up during the discussion and planning of the evaluation. Therefore, student strengths and weaknesses need to be incorporated into future studies on collaboration and clinical reasoning skill development. Likewise, examining how virtual collaboration using a variety of tools embedded in a virtual patient simulation (e.g., chat rooms, discussion boards, forums, video conferencing) should be developed to evaluate their effects on student clinical reasoning skills.

Conclusions

The purpose of this study was to examine audiology students' ability to collaborate online in a designed scaffolded environment. Three groups were formed to achieve this goal, two control groups using no-collaboration and live face-to-face collaboration, and one treatment group using virtual collaboration.

The results imply that lower scores were associated with students receiving more instructor-designed content and higher scores with students receiving less instructor-designed content. Students who received more scaffolds may demonstrate better decision-making outside the training exercise than those who did not. Lower scores on this exercise did not imply lower skills, just a different means by which to obtain those skills.

Author Contributions

Ramy Shaaban: Conceptualization, Formal analysis, Project administration (Lead), Methodology (Equal), Data curation (Equal), Validation (Equal), Writing – original draft (Lead). **Cynthia M. Richburg:** Resources (Lead), Data curation (Equal), Validation (Equal), Writing – review & editing (Lead).

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