Virtual Reality for Teaching Science Vocabulary to Postsecondary Education Students with Intellectual and Developmental Disabilities

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Abstract

The purpose of this study was to examine the use of virtual reality, an emerging technology, to teach college-age students with intellectual disability and autism to acquire science vocabulary words relating to human anatomy. One student with autism and two students with an intellectual disability participated in a multiple baseline across skills (i.e., acquisition of science vocabulary words) design. Data were collected on the three students' abilities to define and label three sets of human anatomy vocabulary words (i.e., bones, muscles, and organs) while using Organon 3D. Students used this application while using the Oculus Rift S, a virtual reality head-mounted display. Results indicated that all students acquired definitions and labeling knowledge for the new science vocabulary terms in the area of human anatomy.

Keywords: Virtual Reality, Intellectual Disability, Autism, College-age Students, Science Vocabulary, & Oculus Rift S

Plain Language Summary

- This study explored if virtual reality could help college students with intellectual disabilities and autism learn science words about the human body.
    - They used a virtual reality headset called an Oculus Rift S and an application called Organon 3D.
    - Three students were in the study, one with autism and two with intellectual disabilities.
- **What we did in this study:** The researchers asked students to locate and name different bones, muscles, and organs in the human body while in virtual reality.
- **Findings:** They found that the students were able to learn and remember the science names and locations of the words.

Students with disabilities are underrepresented in science, technology, engineering, and mathematics (STEM) education (Lee, 2011) due to a variety of barriers. These include misconceptions by parents and teachers about student success in the field of STEM, encouragement of students to take elective-type courses, and teachers who are unprepared to provide an inclusive learning environment for students with disabilities (Lee, 2011). A 2019 National Science Foundation report also found that individuals with disabilities are underrepresented in STEM careers (NSF, 2019). Previous research also notes that there are few role models for individuals with disabilities to look up to within the STEM field (Aksamit et al., 1987; Fonosch et al., 1981). Students with disabilities have also been discouraged from taking STEM courses in school due to misconceptions that they will not be successful, and are then encouraged to focus on non-academic coursework (Kurth et al., 2019). Accessible instructional technologies using Universal Design for Learning principles are means to improve science education for students with disabilities (Izzo et al., 2012). This study examines this topic by using the emerging technology of virtual reality headsets to support improved STEM experiences for students with disabilities.

IDD and STEM

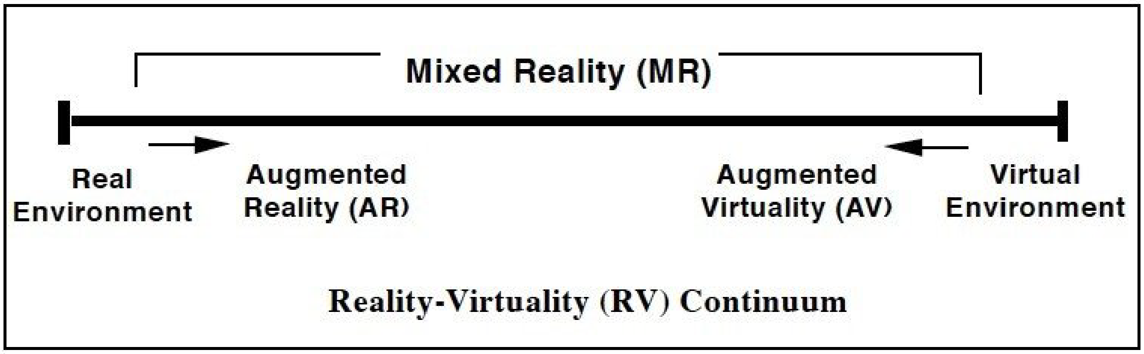
Individuals with intellectual and developmental disabilities (IDD) are part of a broader community of people with disabilities who are underrepresented in STEM. IDD is an umbrella term that can include individuals with intellectual disabilities and/or individuals with other developmental disabilities such as autism (Schalock et al., 2021). Literature reviews of STEM instruction for students with IDD identify significant limitations in the content and instructional strategies represented in the research to date. Courtade et al. (2007) examined 20 years of science education research for students with IDD and found only 11 studies, with all of them being single-subject/case designs and none using computers or technology to teach science concepts. More recently, a similar systematic review conducted by Knight and colleagues (2020) found 12 science education studies focused on students with IDD, only one of which utilized any technology (iPad). In addition, Wright et al.'s (2020) review of how video modeling technology was used to support students with IDD in STEM topics identified only 10 studies. While the research is limited, findings from these studies show that technology tools may be useful in supporting students with IDD in STEM topics.

Virtual Reality and Education

Milgram and Kishino (1994) describe the term virtual reality (VR) as an environment in which the "observer is immersed in, and able to interact with, a completely synthetic world" (p. 2). Further, Milgram and Kishino (1994) argue that VR falls into a continuum of mixed reality displays, including augmented reality (AR) and VR. In this virtuality continuum (Figure 1), the real environment is on one end, and the immersive, completely virtual environment is on the other. AR can be defined as virtual objects being

Figure 1

The Mixed Reality Continuum



interactively overlaid with the user's real surroundings (Azuma, 1999). Recent advances in head-mounted displays (HMD) like the HTC Vive, Oculus Rift, and Meta Quest have expanded opportunities to use these immersive environments for educational and research purposes. For this study, we use the term VR to only refer to immersive VR delivered on head-mounted displays, which aligns with how the term is used in computer science. It explicitly excludes virtual environments involving video games with avatars that are displayed on traditional computer screens.

While the application of VR headsets in science education is relatively recent, several studies have examined the efficacy and utility of VR in supplementing and enhancing learning. A meta-analysis of the effectiveness of VR game-based instruction on student learning outcomes found these environments to be effective (Merchant et al., 2014). In their comparison study, Parong et al. (2018) found that students in the non-VR control group performed better on content tests than those in the VR group. However, students in the VR group scored significantly higher on measures of engagement and motivation.

Immersive Learning and Students with IDD

While there is a growing body of literature focused on the use of AR to support the learning of STEM-related topics, there are even fewer examples of how these immersive learning experiences can support students with IDD. However, those conducted have primarily focused on how VR headsets can be useful in supporting students with IDD. For example, McMahon et al. (2020) investigated exercise gaming in VR. The VR platform that was used during this study was the HTC Vive. The participants also used a stationary bike and the software game Virzoom. Results indicated that all students increased their exercise duration and intensity while using the VR device (McMahon et al., 2020). Malihi et al. (2020) investigated the safety and usability of HMD compared to standard monitor displays of video for individuals with autism. Their study used an Oculus Rift for the HMD device and a standard computer and mouse for a control group during a single, multi-hour session in a research laboratory. They found that the HMD improved realism and a sense of presence for the individual (Malihi et al., 2020). In addition, the results indicated that the HMD group and control group had similar effects, but the HMD option provided "enhanced usability and user experiences" (Malihi et al., 2020, p. 1928).

Although there is limited research that includes individuals with IDD and the use of VR, it has been used generally to support academic experiences (Buzio et al., 2017) and for individuals to have control over their learning in a safe environment (Jeffs, 2009). Therefore, to continue to expand the research on these topics, this study will utilize VR HMDs and how the use of the UDL framework can be used to inform the implementation of emerging technology in the classroom.

Universal Design for Learning (UDL)

The theoretical framework used to guide the study is UDL. This framework is composed of three guidelines: multiple means of engagement, multiple means of representation, and multiple means of action and expression (CAST, 2018). The purpose of each of these principles is to inform instruction so that all learners can access and participate in the learning process. Multiple means of engagement provide options for recruiting interest, sustaining effort and persistence, and self-regulation. Learners engaged in the learning process can span from disengaged to highly engaged; this guideline provides different options for students to spark their learning process. Within the guideline of representation, learners can expect to interact with the learning process through multiple senses and different forms of communication. The final guideline of action and expression aims to let individuals show what they have learned through different methods. These guidelines pose an opportunity to engage students in the learning process through technology. It is essential to keep in mind that VR technology in science does not replace the teacher's current information but is thought of as another means by which science content can be taught. VR provides a different medium for how information is presented (representation). Through the use of apps, students can express what they know in a medium other than traditional paper and pencil (action and expression), and students can connect with the content in a meaningful, hands-on way.

Purpose of the Study

The purpose of this study is to expand the research base for VR in science education for students with IDD. The current study utilizes similar methods to the McMahon et al. (2015) study (e.g., the same multiple-baseline across-skills design, data collection procedures, and population). However, the intervention platforms are different between the two studies. Rather than using a handheld iPad to view AR designed to teach science vocabulary, this study uses a VR headset and a human anatomy application, Organon 3D, to teach the target vocabulary terms. The following research questions are used to guide this study:

1. What are the effects of a VR intervention package, consisting of a VR headset and the Organon 3D application, as the means for teaching specific human anatomy definitions to college-age students with IDD?

2. What are the effects of the same VR intervention package as the means of teaching the location of specific human anatomy structures in the body to college-age students with IDD?
3. What are students' overall perceptions of using the VR intervention package as a tool to learn about human anatomy?

Methods

Participants

Two students with intellectual disabilities (Catelyn and Aria) and one student with ASD (Sam) completed this multiple-baseline across-skills study (Gast et al., 2010). All the participants attended the same inclusive postsecondary education (IPSE) program at a large university in the northwestern United States. We chose pseudonyms for each student to protect their identities. The study initially began with four participants, but one of the participants left the study during the first intervention phase to attend a similar program at another university. We recruited participants for the study by asking for student volunteers within IPSE program courses. All participants met the following inclusion criteria: (a) were enrolled in an IPSE program for students with IDD, (b) did not have a physical disability that hindered their participation in the study, and (c) consented to participate in the study. To attend the IPSE program, students had to qualify for special education services under IDEA in their K-12 education (Individuals with Disabilities Act, 2004); they had to be unable to obtain acceptance into a traditional four-year university; and they had to be seeking to gain independence in a college setting.

All participants had been previously introduced to VR equipment during a Digital Literacy (DL) workshop (a required course for students enrolled in the IPSE program). During the workshop, students were able to try different mixed-reality devices and explore. Some of the students watched 360-degree videos on YouTube VR and some played games such as Beat Saber and EPIC Roller Coasters. All participants had previously demonstrated difficulties in defining and locating particular human body components, which was one of the curricular focus areas of the Health and Wellness course they took within the IPSE program. Table 1 shows the demographic information of the participants in the study.

The researchers conducted a records review and met with IPSE program staff to ensure that all participants met study eligibility criteria, had basic familiarity with VR equipment, and would benefit from learning about human body components. Table 1 provides demographic information for Sam, Catelyn, and Aria.

Table 1

Participant Demographic Information

Name	Age	Gender	Race/Ethnicity	Disability
Sam	20	Male	Caucasian	Autism spectrum disorder
Catelyn	22	Female	Caucasian	Intellectual disability and Attention Deficit Hyperactivity Disorder
Aria	21	Female	Asian	Other Health Impairment

Sam

The review of Sam's educational records revealed that he received special education services under the category of autism. These services included specially designed instruction in reading, writing, math, and social/adaptive skills. Sam's adaptive skills were measured using the Vineland Adaptive Behavior Scales Assessment in 2018. His overall standard score on the assessment was 117, including a 97 for Daily Living skills, and a 92 in Socialization Skills. Within the IPSE program, Sam identified an interest in graphic design. Sam had taken courses for audit through the university in communication and digital media. He also participated in program-specific courses including digital literacy, career planning, and health and wellness. Sam also participated in an internship on campus in a technology lab where he worked 4 hours per week. Some of his duties in the internship revolved around editing documents and reviewing technology applications.

Catelyn

The review of Catelyn's records indicated that she qualified for enrollment into the IPSE program as a student with ID and Attention Deficit Hyperactivity Disorder. IPSE program staff stated that her adaptive skills were similar to the level of her peers within the program. Catelyn participated in multiple internships during her time in the postsecondary education program. Her professional interests revolved around the theater. She had experiences working at multiple local theaters, a daycare, and the music hall at the university. Her audit courses were in the areas of apparel and merchandising, as well as teaching and learning.

Aria

Aria received K-12 special education services first as a student with an Orthopedic Impairment and then as a student with another Other Health Impairment. She was accepted into the IPSE program as a student with ID using the Higher Education Opportunity Act (2008) definition of ID, which allows for acceptance to the program if the student can document significant limitations in cognitive functioning and adaptive behavior and was served as a student with a disability under the Individuals with Disabilities Education Act (Think College, 2020). Medical records indicated that she had been diagnosed with cerebral palsy and left-sided hemiplegia and had undergone several cardiac surgeries. Testing was conducted in 2015 using the Stanford-Binet Intelligence Scale-5th Edition (SB5) and the Comprehensive Test of Nonverbal Intelligence- Second edition (CTONI-2). Aria received a full-scale standard score of 70 on the SB5 and a 72 on the CTONI-2. Aria’s most recent academic achievement testing occurred in 2017 when she was administered the Measurement of Academic Progress (MAP). It should be noted that scores between the 40th and 60th percentile align with grade-level standards. In math, Aria scored in the third percentile, and in reading, she scored in the eighth percentile. Aria’s interests include animals and veterinary medicine. She would like to work in a veterinary clinic. During her time in the postsecondary education program, she took courses for audit in animal science and biology. She also volunteered her time at the local animal shelter.

Setting

All three of the students who participated in the study attended an IPSE program for individuals with IDD at a public university in the northwestern United States. Each of the students was enrolled in two traditional university courses for audit, an internship, and IPSE-specific courses that included health and wellness, digital literacy, independent living, and career planning and professional development. These courses were designed to meet the needs of the students who were enrolled in the IPSE program. All phases of this study occurred in a technology lab located on campus. In the technology lab, there was a large green screen area, with lights and monitors set up around it. There was also a large TV and other computers and technology equipment.

Materials

Assessment Materials

Vocabulary probes were developed based on the study completed by McMahon et al. (2015; see Appendix A). There were three different anatomy-related phases used for the study: (a) bones, (b) muscles, and (c) organs. Ten vocabulary words were selected for each of the three anatomy phases. On each vocabulary assessment, there were 20 questions. The first ten questions were designed to measure the student's ability to match the vocabulary word to the definition correctly. These ten questions were referred to as the definition questions. The definitions were adapted to a more simplified language from their original definitions. For example, the vertebrae were used as a selection of bones to be defined and located by the student. During the study, the definition was "The vertebrae are small bones that make up the backbone." This definition was simplified from the anatomical definition: "one of the bony or cartilaginous segments composing the spinal column" (Merriam-Webster, 2020). The definition questions were presented to the students in a multiple-choice format. There were one correct and three incorrect responses in a field of four potential answers for each item.

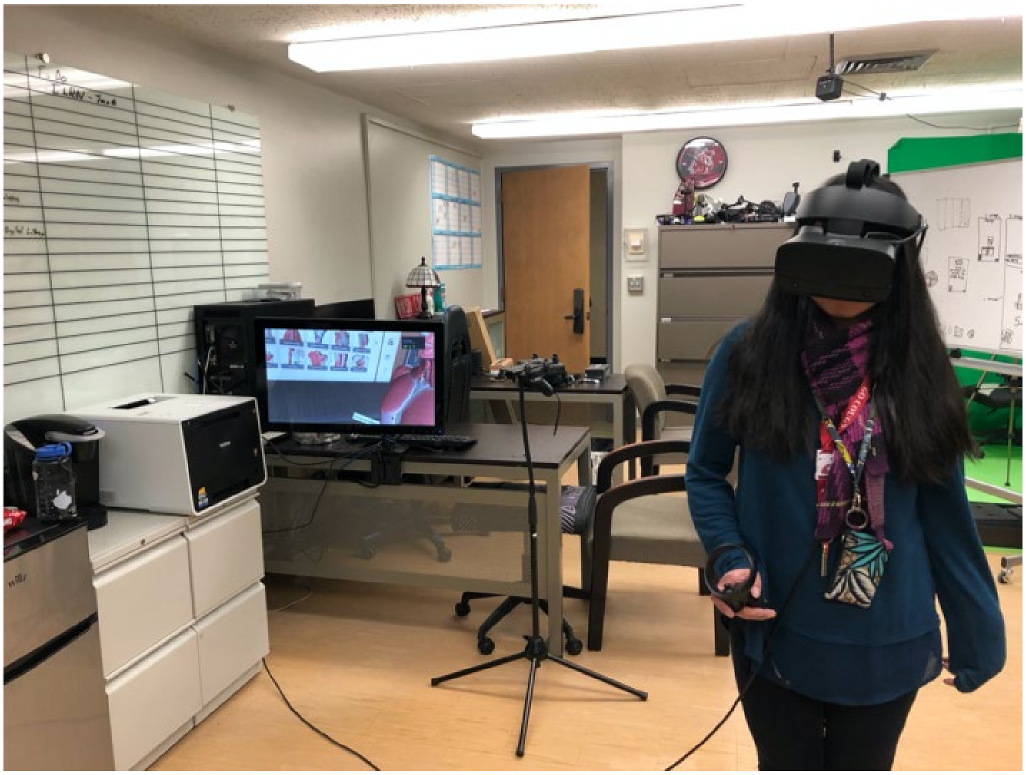
The three incorrect vocabulary words were from the target vocabulary list for the phase in which the student was currently being assessed. For example, when the muscles phase was being tested, the word list consisted of all muscle vocabulary terms. The second set of ten questions was the labeling section of the assessment. For this section, a word bank was given to the student with a list of vocabulary words from the specific phase. The pictures that were used for the labeling section were royalty-free and chosen by the researcher. Some of the photos needed to be modified to identify a specific location (i.e., arrows or a front/back description). Three different formats of each assessment were created that varied the order of the questions, potential answers, and labeling to reduce the student's possibility of remembering correct responses to each of the questions. Each of the nine assessments was designed to measure students' understanding of the vocabulary terms by assessing a student’s ability to define the vocabulary term and label the term with a picture (see Appendix A).

Intervention Materials

The VR system used during the intervention phase was the Oculus Rift S. This head-mounted display (HMD) was connected to a computer. The researcher watched the student participating in the research via the monitor (Figure 2). The app that was used on the Rift S was Organon VR Anatomy. This app is designed for users to manipulate different body systems in a 3D space to locate and define particular bones, muscles, organs, and other anatomical structures. The app allows users to choose different body systems (i.e., skeletal system, heart, and endocrine system); then, the system can be discovered in depth by the user. Once the system is in place, the user can click and move different parts of the system and learn more about them by reading a definition of the body part.

Figure 2

Student Wearing the HMD Attached to the Computer Displaying Organon 3D



When the students participated in the bones and muscles phases, there was no need for them to switch systems in the menu. The researcher instructed students to use the menu to switch to the different body systems based on the organ they were trying to identify during the organs phase. For example, the student would be instructed via a script to go to the menu and choose the digestive system to locate the large intestine. If the kidneys were the next term, they would be instructed to go to the menu and select the urinary system before locating the kidneys.

Variables and Data Collection

The intervention package, including the Organon App and VR headset that were used to learn the new vocabulary terms, was the study's independent variable. VR instruction was implemented systematically across all three phases of the anatomy vocabulary lists. The number of correct responses on the vocabulary assessments was the dependent variable in the study. Since the vocabulary assessments were modified from their original definitions, the students in the study read the assessments independently. The assessments were scored separately, based on the correct responses identified in the definition and labeling sections. The criteria for mastery were met after the student had an upward trend of three consecutive sessions and had two assessments with a score of 80% or higher on each of the definition and labeling sections. The questions were reordered on each of the three different phased assessments. This was done to avoid the memorization of the correct responses. When the student answered one of the responses correctly, it was recorded as a correct response. When the student did not respond correctly or left the response blank, it was marked as incorrect. At the beginning of each session, students were instructed to "do their best," as well as given non-specific words of encouragement.

Procedures

Baseline

During the baseline phase of the study, each student completed a minimum of four sessions of the vocabulary assessments in each of the skill areas: human anatomy bones, human anatomy muscles, and human anatomy organs. The students in the study were advised during this phase to answer the questions that they knew. Some of the students did choose to guess on the baseline questions that they did not know. This was not advised against by the researcher at this time.

VR Training

All the students in the study had previous experience with using VR materials. They knew how to put on the VR headset and use the controllers to navigate in VR. During the student's first session, they were guided by the researcher on what to click on and which trigger to push to highlight and move the body part. The researcher was able to do this as the VR system was connected to a computer. The researcher watched what the students were doing on the monitor to guide them on what they needed to click on or access. Students were advised to click and drag the body part off to the side to access the screen to read the body part's definition and function. A system of least prompts (Shepley et al., 2019) was used with the students to assist them in locating the appropriate body parts. The students were all successful in navigating through the VR system.

VR Vocabulary Intervention. Each intervention session began with the student completing the vocabulary assessment. After this was done, the student used the VR vocabulary intervention to identify and learn each term's definition. Students completed between one and three sessions per day based on the time allotted for each student. A minimum of an hour between each session was guaranteed for each student who completed more than one session a day. During the VR vocabulary intervention, the researcher used a script to guide students by locating each of the ten vocabulary words. The researcher would first read the vocabulary word aloud (i.e., femur, bicep, kidney), then the definition was read, consistent with the definition used in the assessment. For each session, the vocabulary words were read in a randomized order to not allow for memorization by the students.

The system of least prompts (Shepley et al., 2019) was used if the student struggled to find the location of the vocabulary term for more than ten seconds. The Organon 3D Anatomy application reinforces the student to click on the correct body part, as it populates the name of the object as the user scrolls over the anatomical feature. This assists the student in finding the corresponding vocabulary term that the researcher read aloud. The researcher read aloud each one of the vocabulary terms one time with the student. This concluded the session. The students continued in the same phase until the criteria for mastery were achieved. The first phase was human anatomy bones, the second was human anatomy muscles, and finally, human anatomy organs. Each session lasted between 10 and 20 minutes. An example of the VR experience is shown in figure 2, in which a student uses Organon 3D Anatomy to locate different muscles in the human body.

Design

A multiple-baseline across-skills design (Gast et al., 2010) was used to evaluate the relationship between the VR vocabulary intervention and the students' performance in correctly answering the definition and labeling portions of the vocabulary assessment. First, the VR intervention was introduced for vocabulary words relating to human anatomy bones. Then, the VR intervention introduced human anatomy muscles. Lastly, the VR intervention introduced human anatomy organs to the vocabulary list.

Visual Analysis

A visual analysis was used to determine if there was a functional relation between learning definitions and locations of human anatomy terms in VR. Each participant's data will be used to determine if a functional relation exists. The immediacy of effect, level, trend, variability, non-overlapping data, and consistency were all used to support whether there was a functional relation or not.

Inter-observer and Procedural Reliability

The researcher, a graduate student in special education, and one faculty member in special education collected inter-observer reliability (IOR) and procedural reliability data. IOR data were collected for a minimum of 60% of baseline and intervention sessions for each of the students. This is consistent with the replication study. The researcher and faculty member independently scored the vocabulary assessments. The IOR was calculated by dividing the number of agreements of each student's responses by the number of agreements plus disagreements and multiplying that number by 100. By accepted levels of IOR, the researcher's goal was to achieve over 80% agreement (Horner et al., 2005). If 80% was not achieved, the researcher and faculty member would have met and reviewed all the assessment items. The percentage of IOR for the student's assessments was 100% (*M* = 100%).

Procedural reliability was collected for a minimum of 60% during both the baseline and intervention phases of the study. The researcher prompted students to complete the assessment upon arrival, provided the necessary VR equipment, used the script to guide the student through the intervention, and followed the least prompts system. The research assistant was provided with a task analysis checklist of the items to be completed by the researcher (see Appendix B). The level of procedural integrity was calculated by dividing the number of observed researcher behaviors by the number of planned researcher behaviors and multiplying by 100.

Results

Sam

Sam’s average baseline score for the definitions in the human body was 40%, range of 30%-50%. His average baseline score for the labeling portion of the bones phase was 22.5%, range 0%-30%. A visual analysis of Sam’s definitions intervention data showed a decrease in the first three sessions, then a dramatic increase in definitions during the last three sessions, in which he met the criteria for moving to the next phase. A visual analysis for Sam's scores in labeling bones stayed flat for three sessions, and similarly to the definitions, dramatically increased after that. Sam reached the criteria to move to the following phase, which included three consecutive data points in an upward trend and two data points above 80% for correct answers.

In the second phase, Sam exhibited low scores in the baseline phase of the study. He scored an average of 50% on the muscle definitions probes, and range 30%-60%, and 52.5% on the labeling portion of the probes during baseline with a range of 50-50%. A visual analysis during the intervention phase saw his scores increase for both the definitions and labels of the human body muscles. He reached mastery criteria of an upward trend for three consecutive data points and scored above 80% in two of the data points after six sessions.

Sam then moved to phase three of the study, organs of the human body. This phase included the lowest average of baseline scores on definitions and labeling. He scored an average of 24% on the definitions of organs with a range of 10%-40% on probes during the baseline phase and an average of 46% on the labeling portion with a range of 40-60%. A visual analysis showed that Sam's scores were consistent with the baseline scores for one session and then increased. He met the mastery criteria of three data points trending upward two of each of these points being 80% or above by the fifth intervention session. Sam's percentage of non-overlapping data (PND) was 66% for the study which falls into the questionable range at 66% of effectiveness (Scruggs et al., 1998).

Catelyn

Catelyn used the Organon 3D application to learn about the bones, muscles, and organs in the human body. In phase one, bone definitions and locations, Catelyn scored an average of 45% on definitions with a range of 40-50% and 25% for locations for bones during baseline with a range of 10%-40%. A visual analysis of the intervention data showed that Catelyn had an immediate increase in her scores on both the definitions and the labeling portion of the bones probe. She met the mastery criteria of three consecutive data points in an upward trend and two data points above 80% for correct answers. Catelyn was then guided to move to the second phase of the study.

The second phase of the study introduced the definitions and locations of different muscles in the human body. Catelyn's scores in the baseline during this phase were low. She scored an average of 26% on the definitions with a range of 20%-50% and 34% on the muscle labeling portion of the probes with a range of 10%-50%. Once Organon 3D was introduced, her scores on the muscle definitions and labeling probes increased. It took Catelyn seven sessions to reach the mastery criteria and move to the third phase.

The third phase included the definitions and locations of different organs in the human body. Catelyn's scores during the baseline were higher in this phase than in the previous two phases. She scored an average of 55% on the organ definition probe with a range of 50%-70% and an average of 53.3% on the labeling portion of the organ probe with a range of 40%-60%. A visual analysis of the intervention package showed an immediate increase in scores. She reached the mastery criteria of three consecutive data points in an upward trend and two data points above 80% for correct answers. Catelyn's PND was 84%, which falls into the effective range (Scruggs et al., 1998).

Aria

In the first phase, Aria scored an average of 5% on the definitions portion of the probe with a range of 0%-20% and 0% on the labeling portion of the probe during baseline with a range of 0%. A visual analysis of the intervention data showed an immediate increase in the average scores. She met the mastery criteria of three increasing data points and two data points above 80% after five sessions.

The second phase of the intervention, muscles, was then implemented. During the baseline phase for muscles, Aria scored an average of 0% in both definitions and labeling portions of the muscles phase with ranges of 0% as well. There was an immediate increase in average scores during the implementation of the Organon 3D application. Aria reached the mastery criteria in six sessions.

During the final phase of the study, defining and labeling organs, Aria scored an average of 28% during the definitions portion of the baseline phase with a range of 20%-40%. She scored an average of 34% on the organ's labeling portion of the baseline phase with a range of 20%-60%. A visual analysis showed that there was an increase in the data points' level and trend. Aria reached the mastery criteria of three consecutive data points and two data points above 80% in four sessions. Aria's PND was 96%, which indicates that the intervention was highly effective (Scruggs et al., 1998).

Social Validity

At the conclusion of the study, the researcher met with participants individually in the lab and interviewed them about their experiences with virtual reality and the Organon 3D application to assess the social validity of the intervention (Horner et al., 2005). Participants were asked the following open-ended questions: (a) What did you think of the activity? (b) Did you like learning in virtual reality? (c) Can you tell me about what you learned? The researcher transcribed participant responses to the interview questions and then identified both commonalities and differences across responses. Overall, participant responses were positive, both about the intervention itself and the skills learned.One participant, however, noted some frustration with technology glitches and with the length of the intervention.

Discussion

While research regarding the application of immersive technologies to support learners with disabilities is growing and promising, continued studies at this intersection will help determine which emerging technologies are most effective and what types of supports complement immersive learning technologies. The effectiveness of this intervention package in teaching complex science skills to students with IDD adds to the growing body of literature (e.g., Avielo et al., 2016; Maijarern et al., 2018; Syawaludin et al., 2019) by demonstrating an increase in students' comprehension of complex science concepts. The VR headset and Organon 3D application have the ability to take an abstract concept like human anatomy and make it more concrete through enhanced realism and engagement. Student responses during the post-intervention interviews also indicate that realism and engagement may support student learning of these complex anatomical concepts.

Previous research has laid the groundwork for using technology as a means to learn new academic skills. UDL provides the framework for implementation of technology in the classroom and beyond. Emerging technologies, such as the VR intervention package investigated in this study, have become an accessible and novel way for diverse learners to access the curriculum (Davidsson, 2012; McMahon, 2015; Nuanmeesri, 2019; Walker, 2017). As the number of postsecondary options for individuals with disabilities increases, so does access to STEM courses for these individuals who might have been excluded from them previously. This study adds to the growing literature indicating that students with IDD can learn complex scientific concepts through the utilization of immersive technologies. With the use of innovative instructional techniques, such as those investigated in this study, and meaningful opportunities to engage in science coursework at the collegiate level, students with IDD may express interest in taking more science classes or obtaining a career in a science field.

Implications for Practice

This study describes an effective method for integrating technology into a range of classrooms and for specifically learning human anatomy. Recently, remote learning has been implemented in many classrooms worldwide due to the COVID-19 pandemic. This has forced many students and teachers to engage in learning via online platforms. Applications such as Organon 3D allow teachers to provide experiences via science courses to students learning remotely, in person, or in hybrid settings. This and other applications could support learning in critical STEM topics. This VR intervention package would also benefit students, both with and without disabilities, who need repetition to master scientific concepts. In science labs, students often only get one opportunity to complete a project, due to limited resources and/or time. Completing a VR task provides students with many attempts to learn in a low-stakes learning environment.

Limitations and Future Directions

The researchers identified several limitations within the current study. First, participants were exposed to emerging technologies prior to the start of the study via their digital literacy course. In this course, students were taught about mobile devices, AR, and VR. Each of the students participated in one class session where they visited the technology lab and used different emerging technologies as a method of discovery. This previous exposure to emerging technologies, although brief, could have positively influenced students' performance in the current study, and students who were not exposed to emerging technologies beforehand might have performed differently. Second, researchers documented participants' disabilities through a records review. In future studies, using a standardized approach to documenting disability (i.e., administering standardized measures to confirm disability diagnosis prior to the intervention) could support the generalizability of results to specific disability populations. The third limitation of the study was an omission in the instructions provided to participants during the baseline phase. The lead researcher did not specify whether the students could guess on the multiple-choice questions. This could have led to some of the baseline scores being inaccurate due to guessing and getting the question correct, just by chance. Also, during the baseline phase, one of the participants looked at the word bank on the labeling portion of the probe to answer the definition questions. This could have resulted in higher baseline scores during the baseline phase before the researcher realized this was occurring. Once this was discovered during the baseline phase, the lead researcher started giving the definitions and labeling portions of the probes separately to the individuals. The final limitation to the study was that the researchers were not able to conduct a maintenance probe for participants. The COVID-19 pandemic and ensuing university closure to in-person instruction occurred before maintenance probes could be done. However, maintenance data would have allowed the researchers to evaluate participants' vocabulary retention after the conclusion of the intervention phase.

While VR has existed for some time, its use in education, and more specifically, special education, is relatively new. Therefore, research is needed that systematically investigates its effectiveness in supporting learning outcomes and access to the general education curriculum for students with IDD. There are also the practical benefits to this type of research and learning about if the skills learned in VR could be generalized to a real-world setting. With ever-growing libraries of applications and multiple mixed-reality devices, future studies should compare learning outcomes with different tools. As more tools and devices come onto the market, future studies should seek to determine the their effectiveness. Researchers should investigate the immediacy of the effect in the interventions, participants' comfort level with the technology, their ease of use, and their carryover into the classroom. As special educators begin to have access to this technology within their classrooms, researchers need to begin to identify best practices and effective training strategies for general and special educators regarding how to incorporate this technology into inclusive K-12 classroom and college settings.

This replication study adds to the literature in the field of emerging technology in special education. It provides an example of another instructional method for practitioners and expands VR uses in the classroom. Results indicate that participants increased their science vocabulary regarding human anatomy by using VR with the Organon 3D application. This study adds to the existing research literature to support the claim of using VR as a means to learn science vocabulary.

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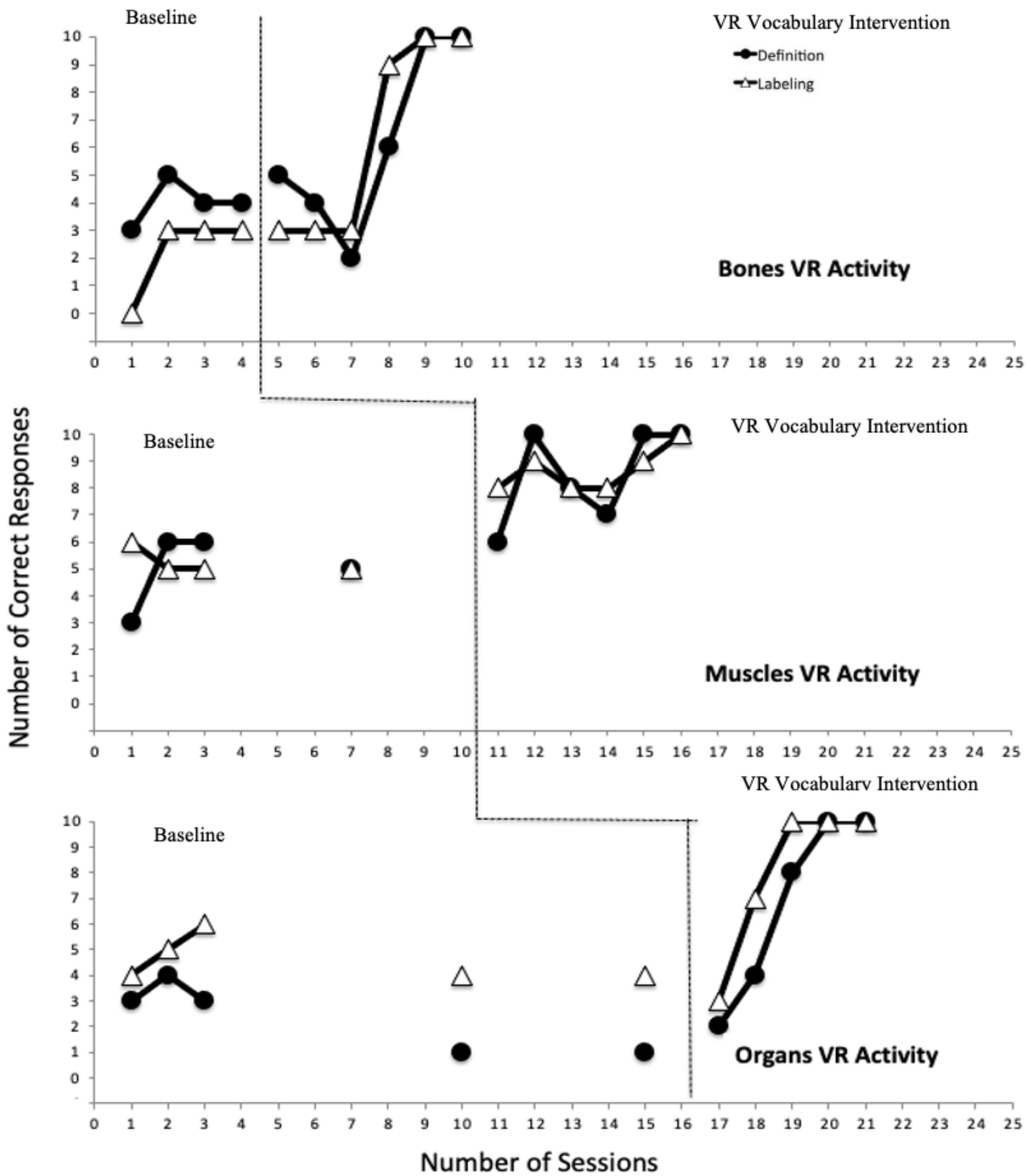
Figure 3

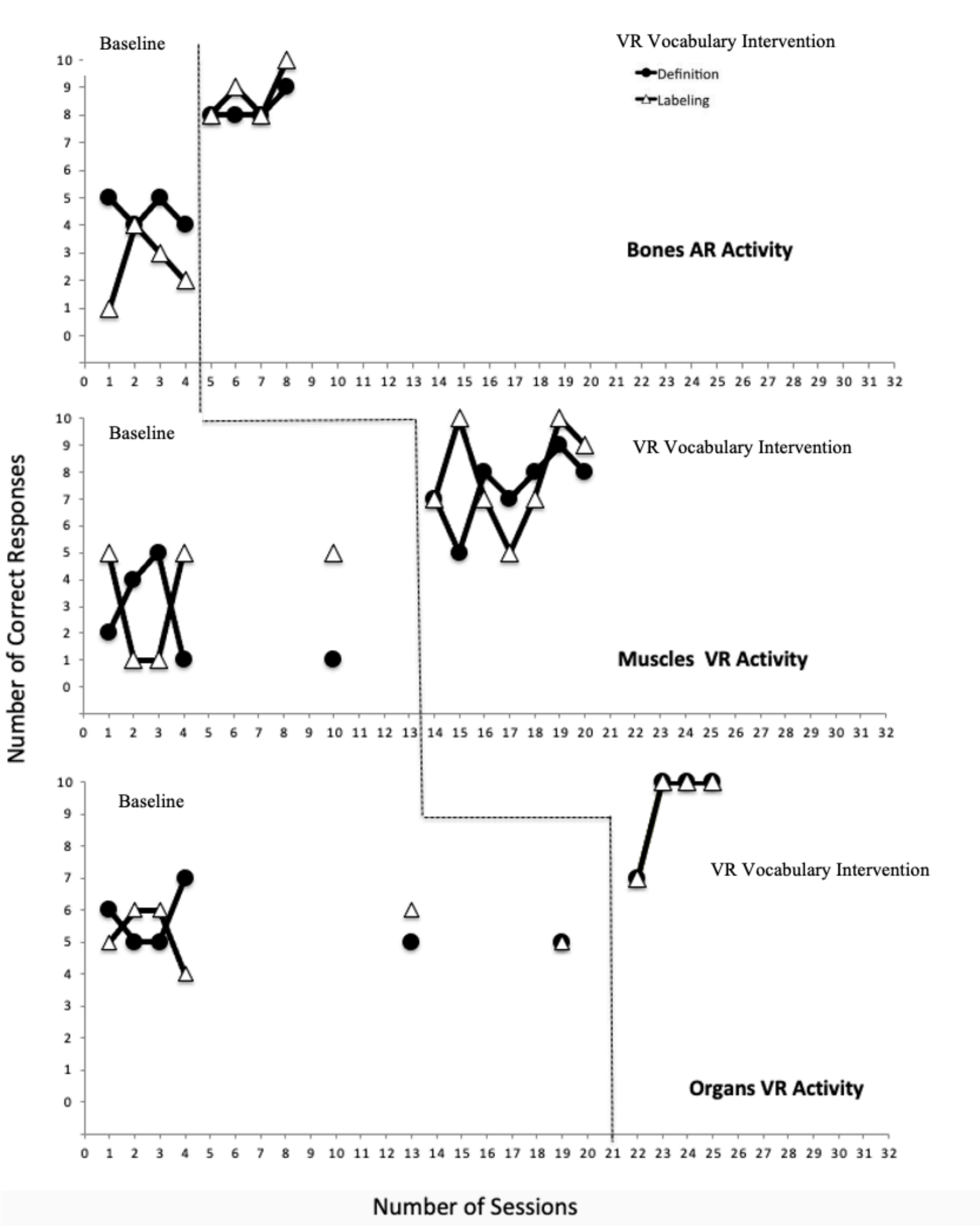
Sam's Results



Data shows mastery criteria of three data points trending upward and two of each of these points being 80% or above in each of the three phases.

Figure 4

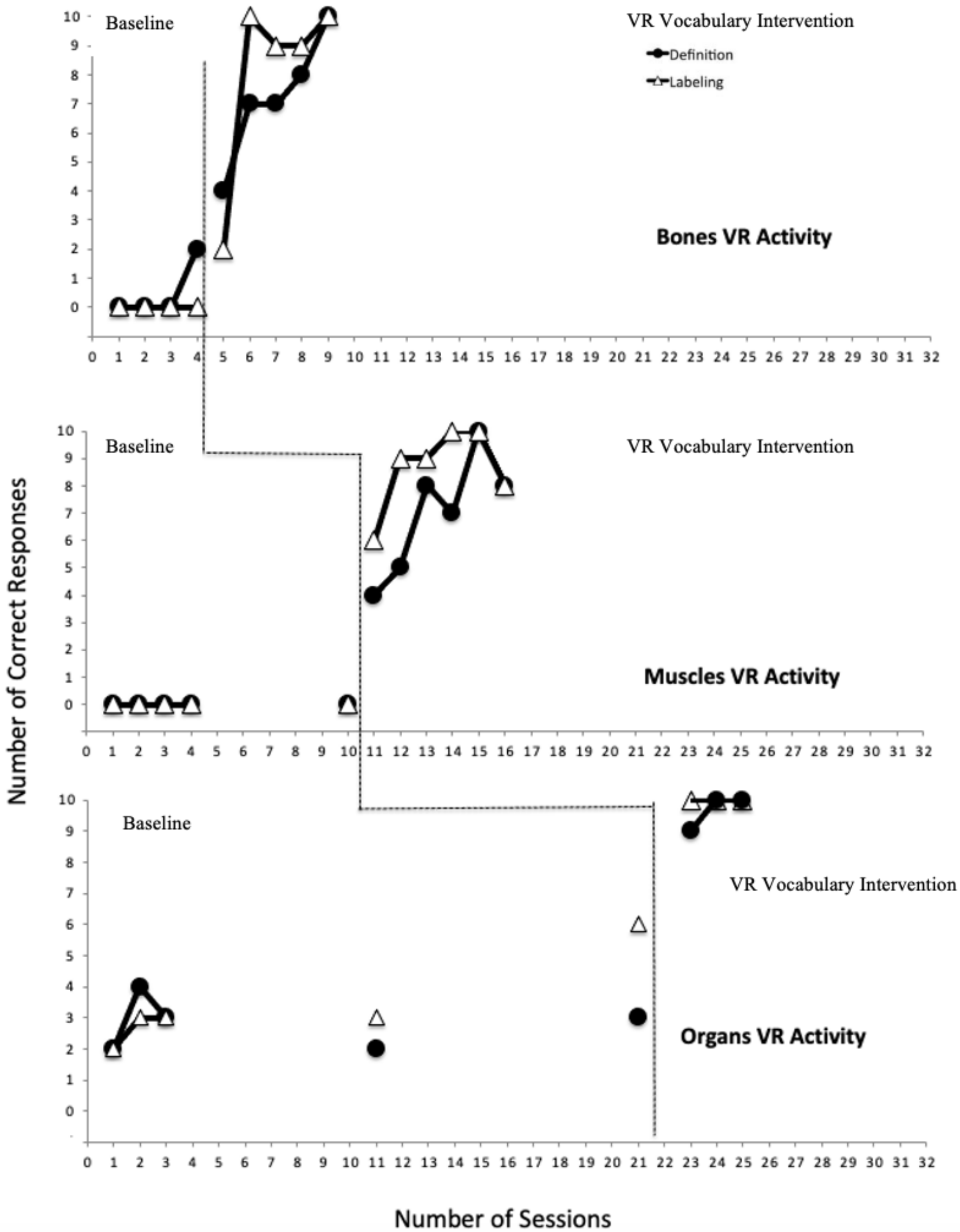
Catelyn's Results



Data shows mastery criteria of three data points trending upward and two of each of these points being 80% or above in each of the three phases.

Figure 5

Aria's Results



Data shows mastery criteria of three data points trending upward and two of each of these points being 80% or above in each of the three phases.

Appendix A

Vocabulary Multiple Choice World List 1 BONES **FORM 1A**

STUDENT__________________

Date____________________________

Definition SCORE	Labeling SCORE

1. _____________is a large bone in the human thigh and the largest bone in the human body
    a. Humerus
    b. Cranium
    c. Femur
    d. Mandible

2. _________________ is a thin, flat bone running down the center of the chest and connecting the ribs
    a. Phalanges
    b. Femur
    c. Patella
    d. Sternum

3. The _____________ is the bone in the lower jaw.
    a. cranium
    b. mandible
    c. tibia
    d. femur

4. The ____________________ is the kneecap.
    a. mandible
    b. phalanges
    c. sternum
    d. patella

5. The collarbone is called the _________________.
    a. mandible
    b. clavicle
    c. femur
    d. vertebrae

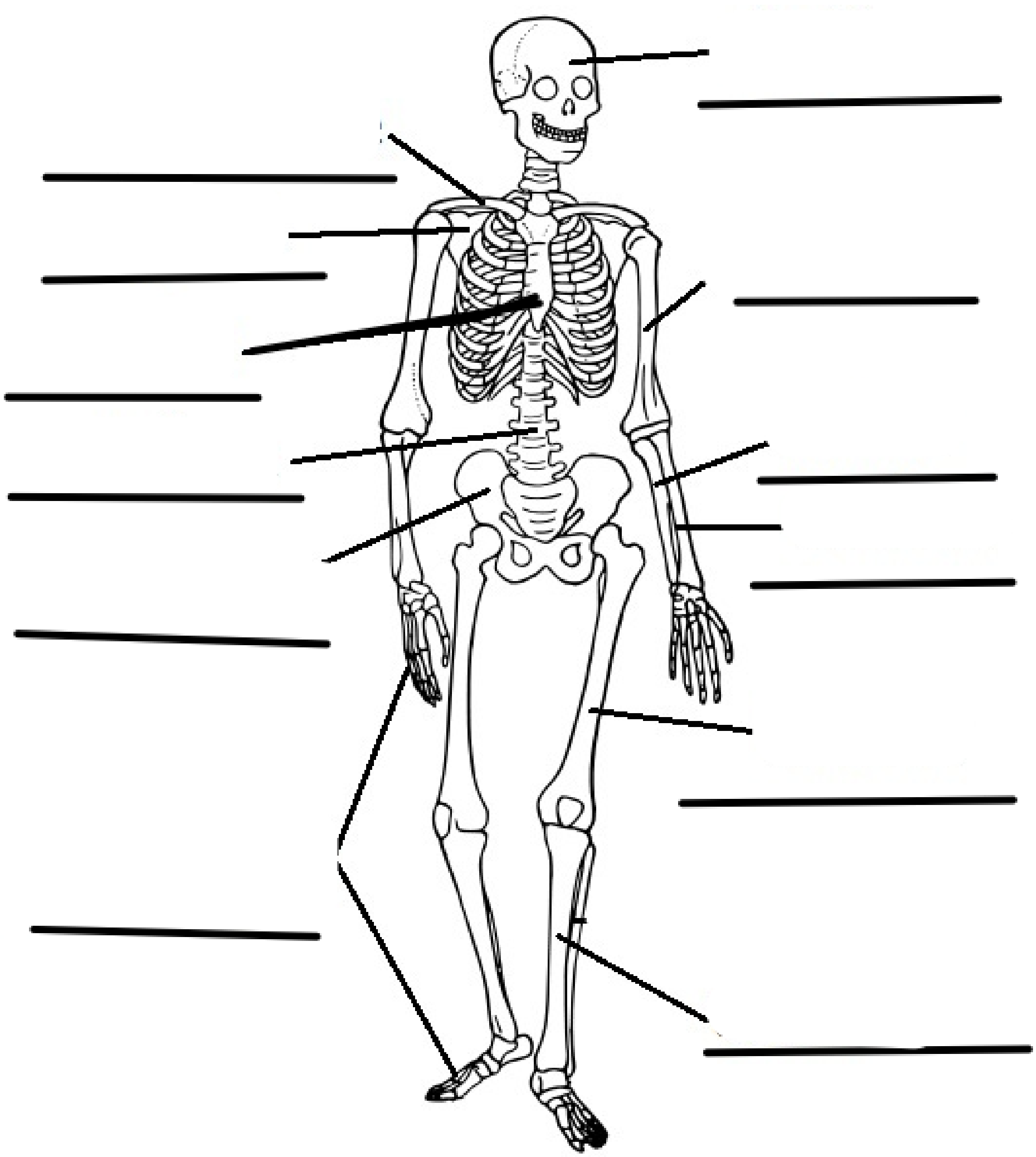
6. ________________ are small bones that make up the backbone.
    a. Cranium
    b. Phalanges
    c. Vertebrae
    d. Clavicle

7. The ____________________ is the bone in the upper arm that connects the shoulder and elbow.
    a. humerus
    b. femur
    c. tibia
    d. vertebrae
8. The _______________________ is the lower part of the trunk of the human body between the abdomen and thighs.
    a. Vertebrae
    b. Pelvis
    c. Femur
    d. Humerus
9. In the human body are ____________________ the most distant part of arm or leg from the human body such as fingers and toes
    a. phalanges
    b. mandible
    c. cranium
    d. vertebrae

10. The _______________ is one of two long bones in the lower leg between the knee and ankle.
    a. Femur
    b. Sternum
    c. Tibia
    d. pelvis

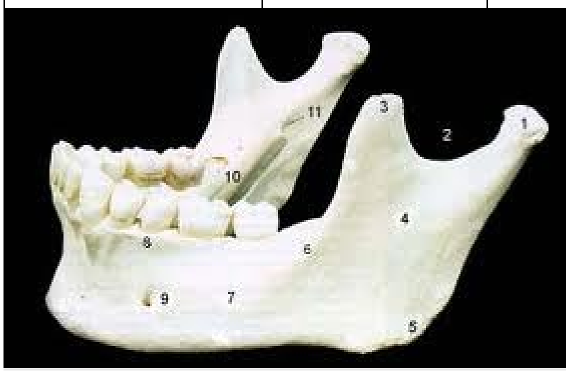
In the Diagram below label the following body parts. There are more options than you will need.

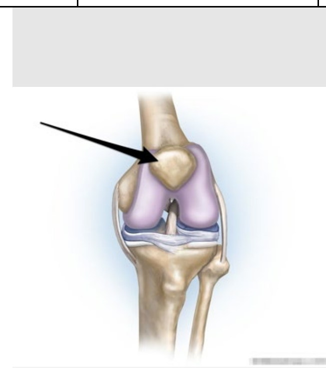
1.) Femur
2.) Pelvis
3.) Sternum
4.) Phalanges
5.) Vertebrae

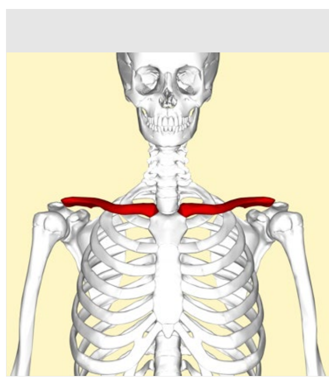


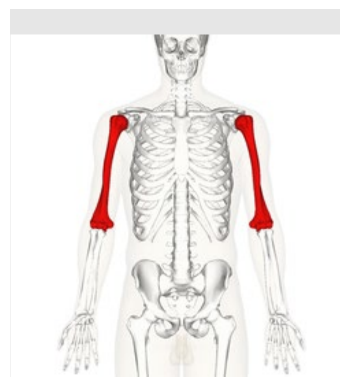
Match these parts of the human body to correct picture below.

1.) Mandible	2.) Patella	3.) Humerus	4.) Clavicle	5.) Vertebrae









Vocabulary Multiple Choice World List 1 MUSCLES FORM 1B

STUDENT__________________

Date____________________________

Definition SCORE	Labeling SCORE

11. The ___________________muscle is a large muscle that lies on the front of the upper arm between the shoulder and the elbow.
    a. quadriceps
    b. bicep
    c. tricep
    d. pectoralis

12. The ________________ major is a thick, fan-shaped muscle, which makes up the bulk of the chest muscle.
    a. pectoralis
    b. abdominal
    c. deltoid
    d. hamstring

13. The ____________________muscle is a large muscle on the back of the upper limb of many vertebrates. It is the muscle principally responsible for extension of the elbow joint
    a. Latissimus dorsi
    b. trapezius
    c. bicep
    d. tricep

14. The _____________ muscle is a rounded, triangular muscle located on the uppermost part of the arm and the top of the shoulder
    a. tricep
    b. bicep
    c. deltoid
    d. pectoralis

15. The ____________________ muscle is a paired muscle running vertically on each side of the anterior wall of the human abdomen.
    a. Latissimus dorsi
    b. abdominal
    c. deltoid
    d. trapezius

16. The ____________________ is a large muscle group that includes the four prevailing muscles on the front of the thigh.
    a. hamstring
    b. quadricep
    c. bicep
    d. tricep
17. The ________________ muscle is the main extensor muscle of the hip.
    a. hamstring
    b. abdominal
    c. gluteal
    d. quadricep

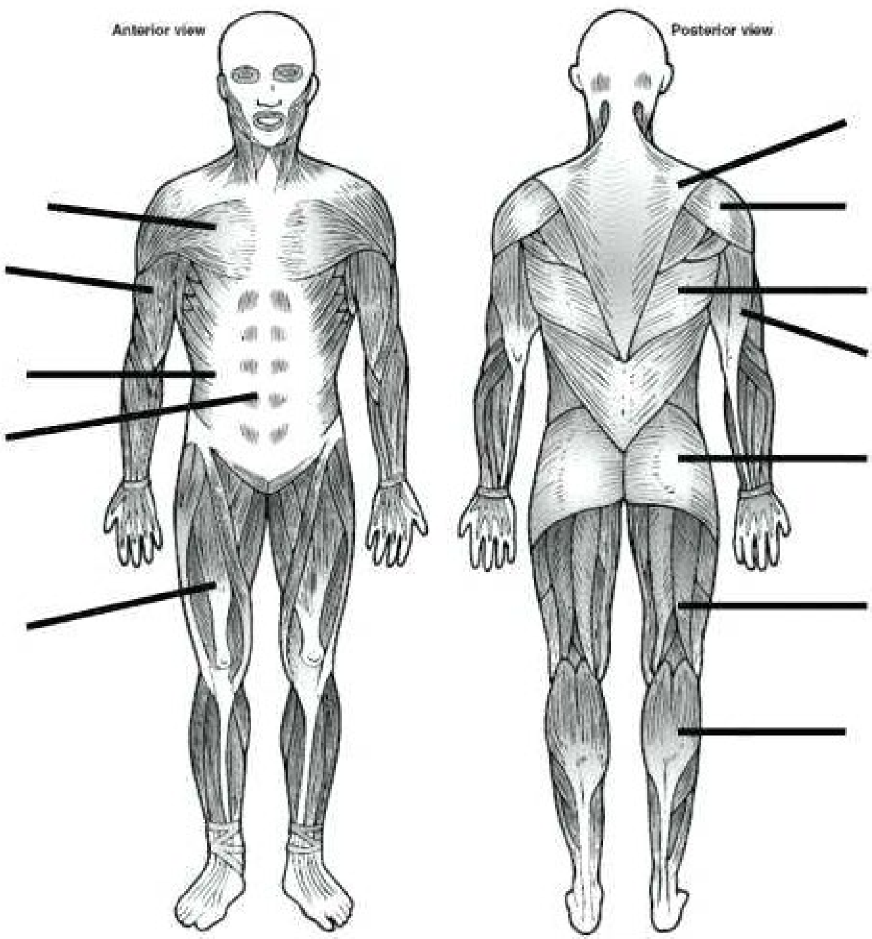
18. The ________________________ muscle is responsible for extension, adduction, transverse extension also known as horizontal abduction, flexion from an extended position, and (medial) internal rotation of the shoulder joint.
    c. tricep
    d. trapezoid
    d. latissimus dorsi
    e. pectoralis

19. The three muscles of the back of the thigh are the _____________________.
    c. hamstring
    d. gluteal muscles
    d. deltoids
    e. quadriceps

20. The ___________________ muscle is one of the major muscles of the back and is responsible for moving, rotating, and stabilizing the scapula
    a. trapezius
    b. bicep
    c. tricep
    d. hamstring

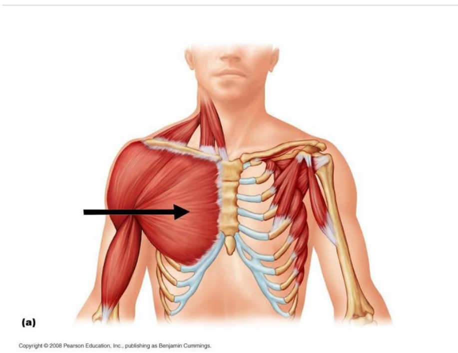
In the Diagram below label the following body parts. There are more options than you will need.

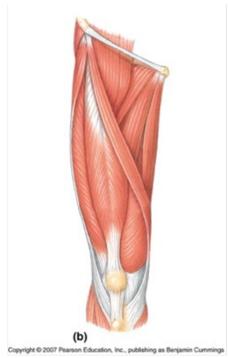
a. deltoid
b. bicep
c. Abdominals
d. trapezius
e. hamstring



Match these parts of the human body to correct picture below.

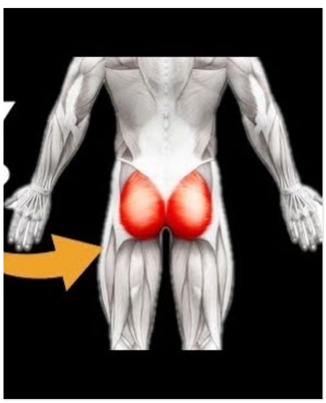
6.) pectoralis	7.) triceps	8.) latissimus dorsi	9.) gluteal	10.) quadricep





Front of leg

________________________ ________________________



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________________________ ________________________

Vocabulary Multiple Choice World List 2 Organs FORM 1C

STUDENT NAME_________________________________

Date _____________________________________

Definition SCORE	Labeling SCORE

21. An organ involved in making and removing blood cells is the ___________________.
    a. spleen
    b. aorta
    c. esophagus
    d. small intestine

22. The ____________________ is the main artery of the body, supplying oxygenated blood to the circulatory system. In humans it passes over the heart from the left ventricle and runs down in front of the backbone.
    a. esophagus
    b. aorta
    c. large intestine
    d. gallbladder

23. The _____________________is a muscular tube that connects the throat to the stomach.
    a. aorta
    b. thyroid
    c. esophagus
    d. pancreas

24. A large gland behind the stomach that secretes digestive enzymes is the _________________.
    a. pancreas
    b. liver
    c. thyroid
    d. gallbladder

25. The _________________is a large gland that secretes hormones regulating growth and development.
    a. large intestine
    b. thyroid
    c. pancreas
    d. esophagus

26. The _____________ is a large, reddish-brown organ located in the upper right portion of the abdominal cavity that secretes bile and can be damaged by excessive drinking.
    a. pancreas
    b. gallbladder
    c. large intestine
    d. liver

27. The ________________ is a long coiled tube where the digestion is completed and nutrients are absorbed by the blood.
    a. pancreas
    b. small intestine
    c. large intestine
    d. liver

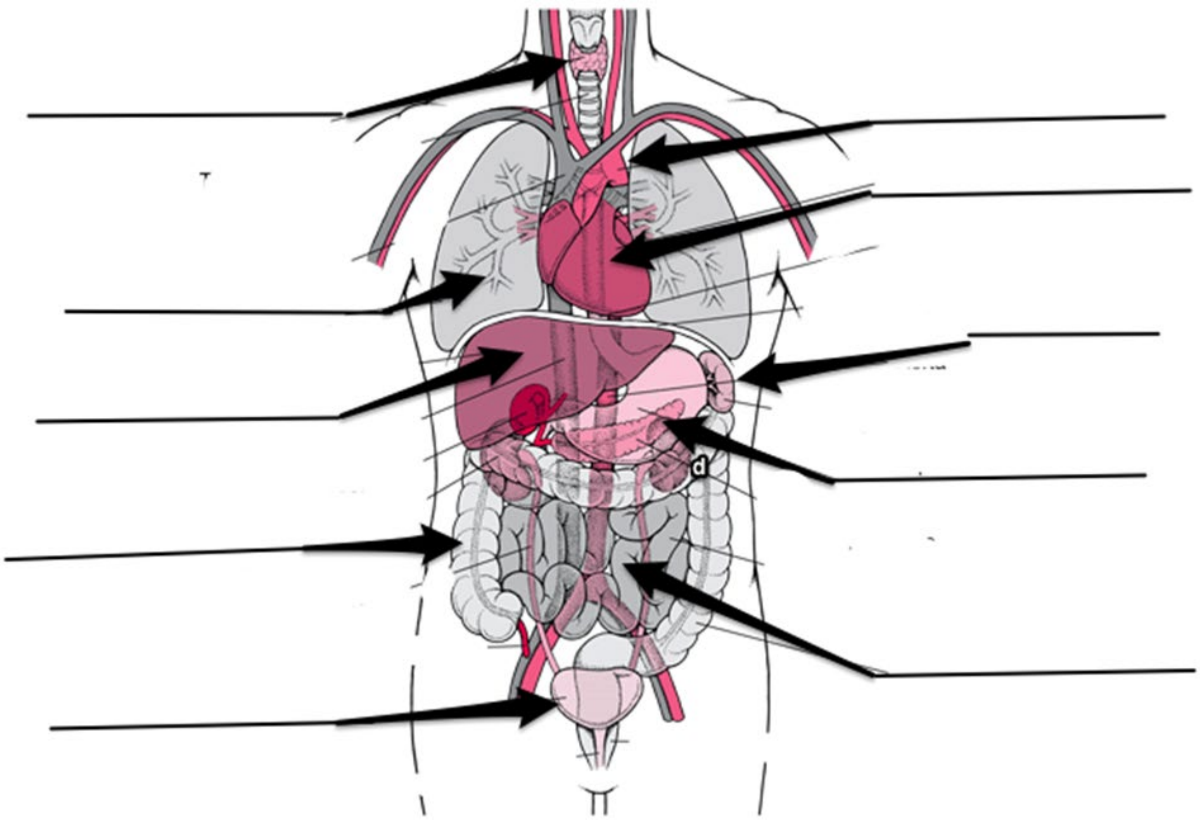
28. The _____________ is the end of the intestine that is wide and short. It includes the cecum, colon, and rectum.
    a. large intestine
    b. small intestine
    c. spleen
    d. aorta

29. The _______________is a small sac-shaped organ beneath the liver, where bile is stored.
    a. aorta
    b. esophagus
    c. gallbladder
    d. liver

30. The _____________ are a pair of organs that remove waste from blood and excrete urine.
    a. thyroid
    b. kidneys
    c. esophagus
    d. aorta

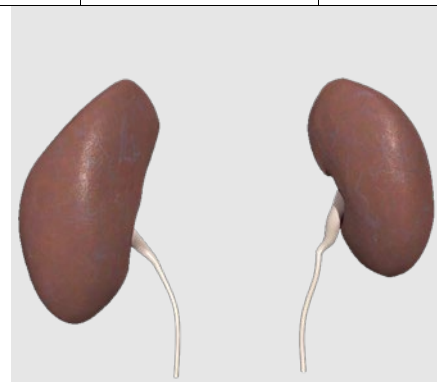
In the diagram below label the following body parts. There are more options than you will need.

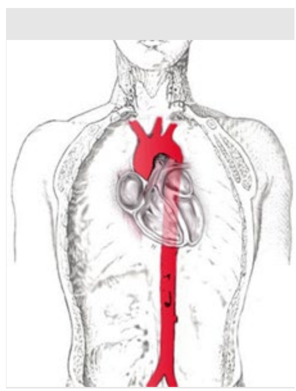
1.) Small intestine
2.) Thyroid
3.) Large intestine
4.) Liver
5.) Kidneys

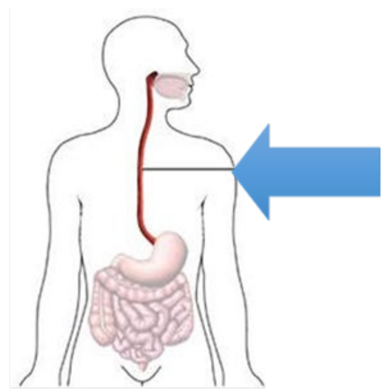


Match these parts of the human body to correct picture below.

11.) Gal lbladder	12.) orta	13.) P ancreas	14.) K idneys	15.) Es ophagus







Appendix B

Treatment Integrity Checklist Vocabulary
Virtual Reality Vocabulary Instruction
Study: VR Vocabulary
Data Collector: ______________________ Date: ______________________________
Coder Name: ________________________

	Observed
1. Ask the student complete the data collection form.	YES NO
2. Observed completion by student of the data collection sheet questions?	YES NO
3. Provided charged VR device to student to practice the vocabulary?	YES NO
4. Instruct the students to open the VR application?	YES NO
5. Watched the student open the VR application on computer monitor?	YES NO
6. Instructed the student to the correct vocabulary (bones, muscles, or organs)?	YES NO or N/A
7. Used the system of least prompts with the student?	YES NO or N/A
8. Observe students practice all the vocabulary words.	YES NO
9. Collected the VR device and data sheet?	YES NO