Technical Report CS18-11

How Static & Dynamic Images Assist Human Problem Solving

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I hereby recognize and pledge to fulfill my responsibilities as defined in the Honor Code, and to maintain the integrity of both myself and the college community as a whole.

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IZAAK MILLER. How Static & Dynamic Images Assist Human Problem Solving.
(Under the direction of Dr. Gregory Kapfhammer.)

ABSTRACT

The ability to easily and quickly express ideas through images has been a major element in teaching since the concept of multimedia creation. In order to evaluate which method more effectively aids humans with respect to the speed of understanding of a new concept and applying the new concept in order to complete a task, this paper presents a study of the effect of between dynamic images vs. static images on human comprehension. The animations presented to humans who are learning the new concept were created with Unity, the game development platform. These animations were evaluated against static frames of the animation to compare which form of teaching a new theory, static images method or dynamic images method, supports the ability for the participant to more quickly comprehend the new information in order to complete the given task. The task completed by the participants in this study is tying a new, unknown knot.

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Chapter 1

Introduction

This chapter briefly discusses the tool that was created in order to conduct the experiments. It also discusses the motivation behind the research that was completed. Furthermore, this chapter also argues the importance of understanding which method of providing information will to aid in problem solving will best enable a person in completing a task and why determining the best instructional method is important. Then, this chapter defines learning, distance learning and the terms static images and dynamic images. The difference between the two is also defined. The introduction also describes the current feasibility of creating animations through various animation applications which can be used for educational purposes. Finally, the goals of this senior thesis are presented before giving an outline of the rest of the work.

1.1 Simulating Tying a Knot

Knot-tying simulations were created created with Unity, the game development platform, in order to evaluate the effectiveness of human problem solving when a human is presented problem solving information through dynamic images. The system created simulates three different animations for tying three different knots. The system animates the process of tying a rope from being completely straight to the final desired knot. The system was created to have a simulation of a knot being tied in an easy to follow fashion. The motivation behind selecting which knots to use in the simulations can be seen in the method of approach in Chapter 3. This system was used in the experiments that were conducted in order to evaluate the effectiveness of information being delivered through dynamic images.

1.2 Motivation

The motivation for this project originally derived from the large impact that sports has on the global community. It is often hard to appreciate how much effort it takes and how difficult it is for teams to perfect the sport that they compete in. All teams are always trying to find some way to have an advantage over other teams. Some of these advantages materialize when looking at different coaching styles. This is where the idea of analyzing the impact of static images versus dynamic images was conceived. When trying to teach new information to players, is it more beneficial to show them static images or create an animation to illustrate the information? This concept can obviously also be applied to more than just sports. Overall, in any teaching environment, there are many different strategies on how to deliver a message so that it will be retained. There is some evidence, discussed in chapter 2, that suggests the traditional style of using static images is more proficient in teaching a new concept. There is also evidence that contradicts this, and instead supports the idea of using dynamic images over static images in order to more effectively teach a new concept, which is also discussed in chapter 2.

This thesis paper will analyze the effectiveness of both static images and dynamic images when presenting new problem solving information.

1.2.1 Why Unity?

Unity is an all-in-one editor that supports the development of both 2D and 3D animations. The user interface is a built in system which allows the developer to create user interfaces fast and intuitively. Unity Technologies offers a platform for creating beautiful and engaging 2D, 3D, VR, and AR games and apps. A powerful graphics engine and full-featured editor enable you to realize your creative vision fast, and deliver your content to virtually any media or device. Unity is the leading global game industry software. More games are made with Unity than with any other game technology [24]. Since Unity is a very popular software, there are large number of forums and thorough documentation. This is important because in order to create a realistic animation ropes being tied with accurate physics, a powerful graphics engine was needed. Unity will provide all the necessary functionalities that will allowed for the creation of the system that will animate the ropes being tied.

1.3 Importance of Research

Education has a large impact on society and plays a key role in the advancement of technology. Over the last 15 years, the desire to better understand how to use technology to teach more effectively has increased as seen in Figure 2.2. The goal of the current study is to increase our understanding of memory retention and humans' ability to learn with respect to methods of background background knowledge presentation. This research creates specific guidelines on when and how to use dynamic images given the results of the experiments conducted for this senior thesis. This senior thesis is another step forward in the process of determining what teaching methods are most effective. Understanding the best way to design learning experiences for students can enhance the amount of information gained during a specific teaching event. The ability to teach through distance learning has also become increasingly popular [?]. Being able to more effectively acquire knowledge will greatly benefit the advancement of human society.

1.4 Defining Learning

Before determining which method of delivering problem solving information is the most effective at aiding humans in learning, the term learning must be defined. Learning has been defined in numerous ways by many different theorists, researchers and educational practitioners. One definition presented by Shuell [11] is "Learning is an enduring change in behavior, or in the capacity to behave in a given fashion, which results from practice or other forms of experience". Learning occurs when the changes in either the form or frequency of performance is observed. Learning occurs when the learner exhibits a proper response after a presentation of a specific environmental stimulus occurs. An example given is when a learner is presented with a math flashcard showing the equation "$2 + 4 = ?$" and they responded with an answer of "6". In this example, the equation is the stimulus and the proper answer is the response given. The key element of learning is when the stimulus and the response has a correct association. A good practice of learning occurs when the association between the stimulus and response is made, strengthened, and maintained.

1.5 Distance Learning

There are many reasons that education might be unobtainable. One of those main reasons is the inability to be in the specific location relevant to the learning event. Distance learning allows students to further their education without having to physically be in a specific location. This is important because it allows for an increased number and range of people that could be educated who would otherwise be unable to obtain the education before. There are also some circumstances such as an emergency situation where someone is unable to perform a specific life-saving task. Distance learning could quickly and efficiently provide the user with the life saving knowledge they desperately need. There are many different benefits of improving our ability to use distance learning. This study helps us be one step closer to deciding the most effective way to deliver problem solving information.

1.6 Learning Design

According to Dr. Grace Clifton [10], learning design is defined as the practice of planning, sequencing, and managing learning activities by using Information and Communications Technologies (ICT) based tools to support both design and delivery. The purpose of learning design is to describe the educational intentions in a particular learning context and in this case the intent of teaching through dynamic images. One reason for focusing on learning design is that it allows educators to devise a systematic approach to the development of a method of teaching that supports a more effective integration of technologies for learning [10]. This senior thesis reinforces this methodology of teaching by determining whether presenting information through dynamic images is more beneficial to the learner than presenting information through static images.

1.7 Defining Static Images

Static images are visual images that do not move. There are many pixels in an image depending on the quality of the image. A pixel is an area of illumination on a display screen, one of many from which an image is composed. A lower quality image would contain around 180 pixel. A higher quality image will have around 1080 pixels, which allows for a higher definition of the image. The highest quality of an image with the current technology is 4000 pixels in one image. In a static image none of the pixels HS (Hue, Saturation, and Value) will change.

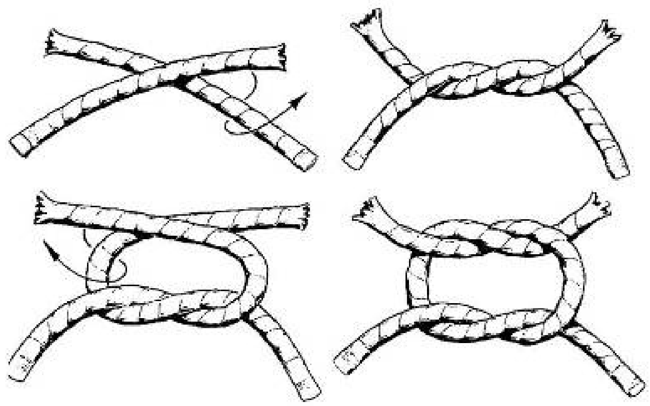


Figure 1.1: Example of static images.

Figure 1.1 displays an example of a static image that is used in the experiment which is covered later in chapter 4. Here, it is clear that the image will not have any changing pixels. It will remain in the same state for the entire presentation of problem solving information.

1.8 Defining Dynamic Images

Dynamic images are a combination of multiple static images in order to make an image appear to move, often referred to as an animation. A dynamic image's pixels' HSV values will consistently change in order to display a new image.

The process of creating a dynamic image is called dynamic imaging. Dynamic imaging is the action of combining digital images on top of each other to create one visual that will be looped over and displayed on the display screen.

It is not possible to give an example of a dynamic image in this document because the state of the pixels in a dynamic image are consistently changing hence the name. The dynamic image looks similar to the static image in Figure 1.1, but instead of the arrows in the drawing, the image will actually move the string in the direction of the arrows. In a dynamic image, the four images are replaced with just one image that is moving in the way indicated by the four static images in the figure.

1.9 Other Tools

1.9.1 Knots 3D

Knots 3D is an app available in the Apple App store for any iOS device. This app is able to quickly instruct a user on how to tie over 120 different knots including some of the most difficult knots. This app is used by arborists, fishermen, firefighters, climbers, military, and boy scouts.

This app allows the user to visualize what the knot of interest looks like in 360 degrees. Knots 3D creates a 3D knot that you can look at from any angle. This app also allows you to zoom in to focus on specific parts of the knot. It also allows the user to watch the knot tie itself. If the user is interested in trying to tie the knot on their own, then they can use their finger to tie and untie the knot being taught. Figure 1.2 shows an example of one of the knots that can be learned through the Knots 3D application.

Knots 3D is a good demonstration of other applications or systems that are able to use dynamic images as a teaching tool. This app allows anyone to have access to a wide range of information. This shows the power of our ability to teach others with animations through applications that can be downloaded instantly no cost at all or for a small one-time fee. Knots 3D is a good example of the incredible amount of different uses for dynamic images to teach problem solving information. This senior

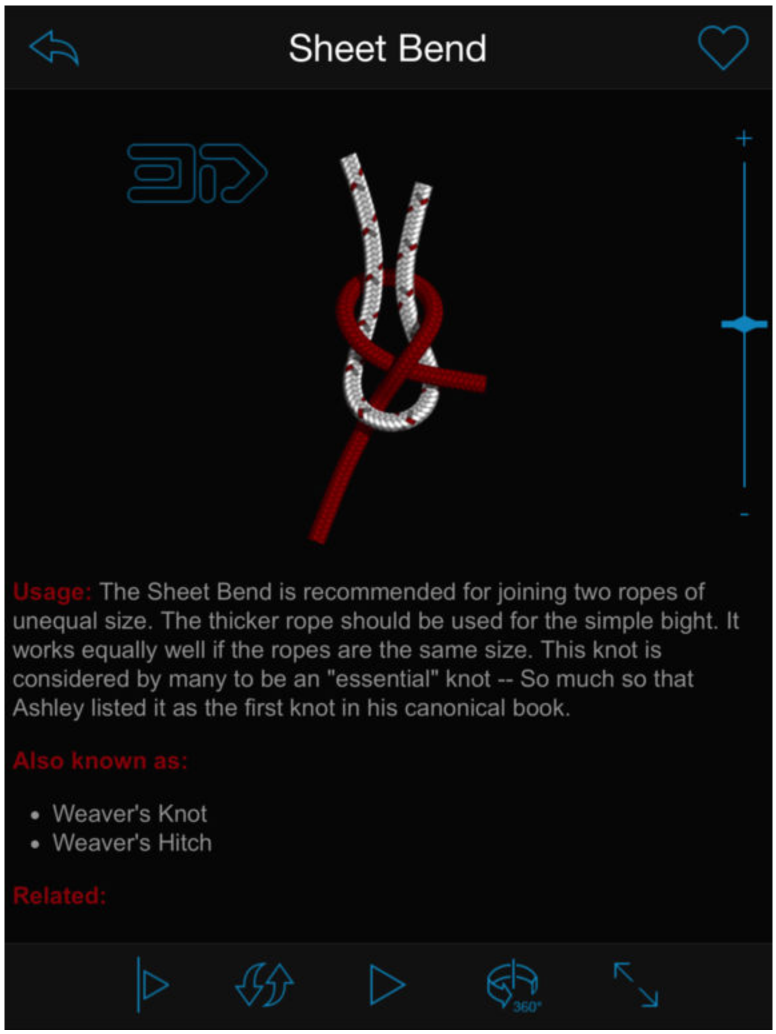


Figure 1.2: Example of Knots 3D application found on the Apple App store [4].

thesis aims to prove the effectiveness of teaching through dynamic images in order to exemplify the amount of applications and systems that use dynamic images as an effective means of presenting information.

1.9.2 CrazyTalk Animator 3

CrazyTalk Animator3 is a free-to-download animation software that allows users of all experience levels to create professional animations and presentations with minimal amounts of effort. This application grants users the ability to quickly animate an image, logo, or prop by applying the motion effects provided by the application. CrazyTalk Animator3 has a complete 2D animation environment that provides the ability to enhance any scene by controlling the animation, scene, prop dynamics, and the special effects. There is a useful in-screen object editing tool as well as a full featured navigation tool. These editing tools allow the user to select, transform, and flip any object in the scene. The navigation tool lets the user zoom, pan, and rotate the camera in order to get the desired camera angle. Furthermore, there are two editing engines: the "Composer" mode gives the user the ability to control the objects and prop setup and the "Stage" mode is used to animation editing. Figure 1.3 shows an example of one of the animation editing tools that can be used to control the velocity and direction of an object. Figure 1.3 also shows the Prop Key Editor that controls the properties associated with a specific prop. These demonstrate the easy to use tools that are provided inside the CrazyTalk Animator3 application.

CrazyTalk Animator3 is another application that enforces the argument that educational animations can be very easy to create.

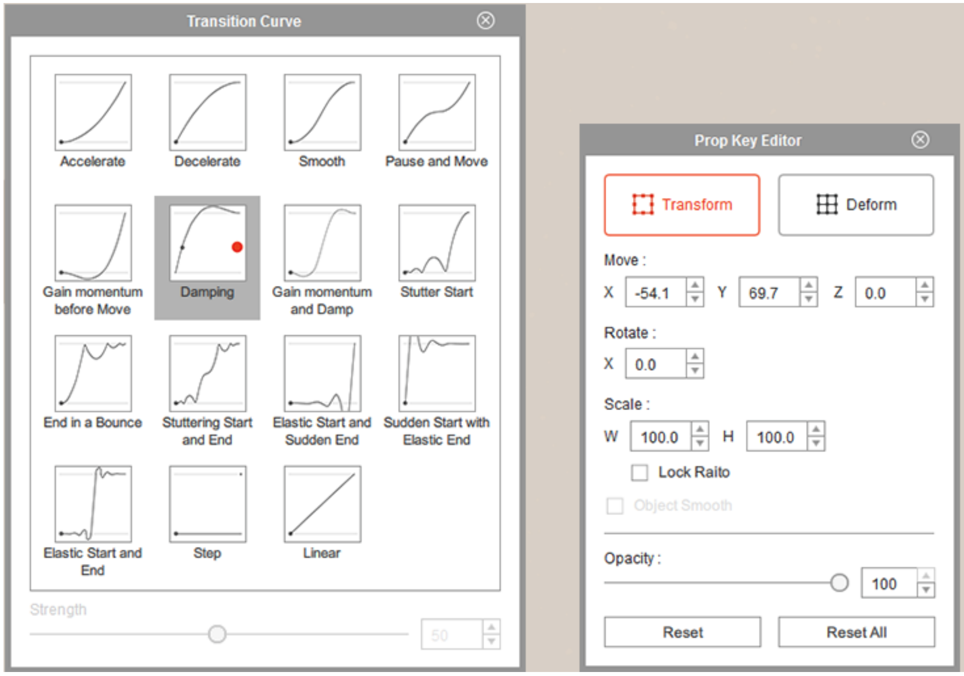


Figure 1.3: Example of animation editing tool and prop editing tool provided by CrazyTalk Animator3 [15].

1.10 Goals of the Project

There are many different strategies when it comes to teaching. An example of one approach is called differentiated instruction. There are also many different ways in which the information is presented to students, whether it be the organization of the material or the pace of the information being presented. These different styles and strategies lead to many different questions on how to best educate students.

This senior thesis was designed to help advance the process of creating learning designs and enhance the ability to teach through the method of distance learning. The purpose of this paper is to specifically answer the following questions:

When presenting problem-solving information, will students retain more information after being given the information through static images or dynamic images? Which method will allow students to better retain the information and then apply the information to a specific task? This senior thesis sought to answer these questions by running a series of experiments on a group of students with little background knowledge. The students were given the information through one of the two ways: (1)the information was displayed in series of static images that was accompanied with an audio instructions or the information will be displayed with dynamic images that was accompanied by the same audio instructions. The students will then be asked to complete a task and their performance will be evaluated. More information on the process of the experiment and evaluation is provided in chapter 3.

The hypothesis of this thesis paper was that the dynamic images are more beneficial at helping people apply problem solving information than the alternate method of using static images.

1.11 Thesis Outline

This senior thesis presents many different articles and references related to the research conducted in this paper. Chapter 2 discusses the related works such as an analysis of 26 different studies to compare the effectiveness of teaching between dynamic and static visualizations. Furthermore, there are articles arguing the results of the analytical as well as recent studies discussing learning design and distance education. Chapter 2 also discusses the impact of learning design, the importance of creating an instructional design around the ability of the learner and the increase of interest in being able to teach through a method called "Distance Learning". Chapter 3 states how this senior thesis designed the experiments to be created and the methodology behind the experiments. Chapter 4 presents how the experiment was created through Processing. Finally, Chapter 5 presents the results of the research and interprets the significance of the results. After providing some concluding statements, it then explores ideas of potential future work.

Chapter 2

Related Work

The idea of comparing the effectiveness between static and dynamic images has drawn more attention in recent years as the ability to create computer-based animations and videos has become easier. There have been numerous studies that try to have evaluate the effectiveness of instructional animations versus static pictures when deciding which is a better solution for learning and understanding a new concept.

2.1 Meta-analysis of Instructional Animations versus Static Pictures

One study done by Tim Höffler [17] analyzes 26 different studies which create comparisons of dynamic and static visualizations. The goal of the study was to integrate the findings of a large number of studies, to calculate overall effects and determine any variables that may have an impact on the learning and understanding of an idea. The study searched through databases looking at abstracts and using descriptors such as "animations", "dynamic picture", "static picture", and "simulation" to find previous studies in order to create a large sample of studies to analyze. This data of studies was then used to try and calculate overall-effects and to identify possible moderator variables and develop an overall consensus about the performance of animations over static images. When ignoring moderator variables, this study found that there was a clear advantage of non-interactive animations over static images. However, the advantage was only a small to medium effect but large enough to make an impact in the understanding of a concept. In particular, using representational animations, an animation that uses motion in that animation which is directly relate to the topic to be learned rather than animation that is in the background or decorative, over decorational animation appeared to be far superior. Tim Höffler concluded the paper by stating that he believed that animations are capable, in certain circumstances, of being effective in teaching but that an animation is not a solution for all learning environments [17]. Instead of analyzing many different scenarios where animations could potentially be beneficial, this proposed research will be conducted on the areas of learning that animations appear to be the most advantageous.

2.2 The Influence of Visual Cognitive Style

Another study done by Tim Höffler [18] took sixty high-school students from several different schools in Germany and randomly assigned and equally distributed them to one of the two groups. One group was taught with static pictures and the other group was taught with animations. These students were taught about the primary reactions that occur in photosynthesis. Both groups being taught the subject had little prior knowledge of photosynthesis. The students were then either given 16 static images or 16 animations and both were combined with a brief text explaining the information being presented. The difference between the static images and the animations was the static images illustrated the movements with arrows whereas the animations acted out the movements. The study concluded that neither animations nor static pictures were generally superior when provided instructional static images versus instructional animations. This contradicts with the study discussed above. However, this study also noted that not enough participants were used to have much statistical power. In order to further prove that neither static images nor dynamic images are superior, they would recommend using more participants.

2.3 Debating Effectiveness of Dynamic Images

In a paper about the increase of multimedia, use of text, graphics, animation, pictures, video and sound to present information, in a learning setting by Lawrence Najjar[21], discusses the assumption that multimedia information helps people learn. Lawrence argues that this assumption appears to be based more on personal belief rather than on scientifically proven fact. Lawrence disputes the claim by a meta-analysis done on over 200 studies that suggest when information was delivered in the form of an animation that learning was higher than when the information was presented in the traditional setting in the form of lectures. Lawrence suggests many possible explanations for the results of the meta-analysis. The explanations provided by Lawrence are as follows:

Instructional Method The first explanation provided by Lawrence is called the Instructional Method explanation. Lawrence argues that the computer-based instructions, creating the animations or multimedia, forces the instructor to organize and structure the learning material in a better fashion. When the instructor uses the traditional method of teaching with just using static images, they will be less likely to reevaluate the organization and structure of the information they are presenting.

Interactivity The second explanation stated by Lawrence is the level of interactivity from students increases when there is more multimedia for students. Lawrence discusses 75 learning studies [5] [13] that found that people learn material faster and have better attitudes toward learning the material when they learn in an interactive instructional environment. The advantage of computer-based multimedia instruction over the traditional lecture may increase interactivity of participants may be due to the increased interaction. However, the increase in retention of the information is more likely because of the increase in the interactivity not the way the information is being presented.

Control of Learning Pace The third argument made by Lawrence is the ability to control the learning pace. The computer-based multimedia instruction allows the learner to control the pace of which they learn instead of a forced paced of learning set in the traditional lecture setting.

Novelty The fourth argument and perhaps the strongest argument is the novelty behind the new delivery of the information. The information being taught using multimedia may seem more novel and stimulation that information being taught in a traditional setting. There may be an initial increasing in higher learning advantages but after the novelty wears off the learning advantages decreased. This is supported by analysis of almost 40 multimedia studies [1][8][9][19], which found that the learning improvements improved in the first four weeks, but after 8 weeks the improvements decreased back to the normal learning rate.

Although these explanations for the advantages described above are related to the idea of comparing multimedia and the traditional classroom lectures, they still offer some form of variability that could occur when conducting these experiments. All of these related works have discussed a number of variables that can affect the outcome of the study. The experiments created during this analysis tried to minimize the amount of variables that are present in the study. The paper by Lawrence suggests that depending on the different forms of information to be learned that there are a number of potential explanations that could justify why teaching with dynamic images appear to be superior over teaching with static images.

In Lawrence's paper, he provides some suggestions on how the information being taught ought to be presented. Figure 2.1 shows that there are a number of different suggested methods.

Empirically-Supported Suggestions for Allocating Media

Information to be Learned	***Suggested Presentation Media***
Assembly instructions	Text with supportive pictures
Procedural information	Explanatory text with a diagram or animation
Problem solving information	Animation with explanatory verbal narration
Recognition information	Pictures
Spatial information	Pictures
Small amounts of verbal information for a short time	Sound
Story details	Video with a soundtrack (or text with supportive illustrations)

Figure 2.1: Suggested methods of presenting information.

This senior thesis investigates the effectiveness of presenting problem solving information with an animation (dynamic image) with an explanatory verbal narration. How this experiment was done is discussed further in chapter 3.

2.4 Memory Retention

A recent study by Candan and et al [6] published in 2016 examined whether dynamic images benefit memory when visual resources are limited. The investigated the short-term retention of brief stimuli using a rapid serial visual presentation with short videos and static frames. By using the rapid serial visual presentation, they were able to control the speed of the information being presented during the experiments aiding them in measuring the limits of visual short-term memory. A typical rapid serial visual presentation consists of a series of very brief images presented to the viewer without breaks. This is very similar to the experiment throughout this senior thesis.

In the study done by Candan and et al, they wanted to answer the questions: Are dynamic images remembered better than comparable still images. In order to answer this question, they presented viewers with brief sequences of short clips and of frames taken from Hollywood movies. The study focused on recognition memory to examine the effects of exposure on later memory as well as the retention of information. The results showed that memory retention increased with longer exposure to the dynamic images. But more importantly, overall memory retention for dynamic images was greater than the memory retention after being shown static images for the same duration as the dynamic images. However, the increase in memory retention was not one of large significance but still notable. One potential reason for the increase in memory retention discussed in this study is that the motion in the dynamic image may increase the attentional focus therefore enhancing the memorization. They believe that the presence of motion is the main factor behind the slight increase in memory performance. They argue that the processing of dynamic images is not simply the sum of motion information, but instead that dynamic stimuli offer a qualitatively different experience that differentiates itself from the processing of static images. Furthermore, this indicates that we can efficiently retain dynamic information even when we have limited access to it. They argue that dynamic images provide richer and more naturalistic information compared to static scenes and also appear to be better at providing information when there is a limitation due to exposure duration. Overall, this study offers some insight on the comparison between processing dynamic images and processing static images.

This study is important because it closely relates to the research and experiments run by this senior thesis. The research questions are very similar but have there significant differences. Candan's research focused on the ability to retain the information given to each viewer based on the duration of the static images and dynamic images being shown. Candan's study does not ask the participants to then apply the information given to them to complete a specific task. This senior thesis looks to analyze the memory performance between static images and dynamic images in order to solve a problem.

2.5 Impact of Learning Design

A paper published in the *International Review of Research in Open and Distributed Learning* journal by Dr. Grace Clifton [10] in 2017 examines the impact of "learning design" in distance learning and on the teaching experience. Clifton examines the education process provided by the Open University which is the largest provider of distance-learning, part-time undergraduate and postgraduate study in the United Kingdom. The Open University (OU) allows students to register without any formal entry qualifications and be located anywhere in the world. The teaching methodologies used at OU are different then the traditional university setting. Clifton describes the different teaching method as "blended learning" in that it can take place in a face-to-face but can also be taught at a distance through the use of on-line tutorials, forums, and one-on-one phone calls.

Clifton states that focusing on the learning design is vital for two main reasons. First, it is important that the structure and organization of the material to be taught is easily distributed to students learning and working at a distance. Second, it is more difficult for a university using distance learning to identify and fix problems involving the material being taught. Analyzing the learning design before distributing the information to be taught helps identify potential issues prior to the distribution.

Considering the learning design of an educational course is important because it gives the instructor the ability to enhance the course by determining when it is most suitable to use dynamic images as a method of teaching. As previously suggested by Lawrence, one suitable situation to use dynamic images accompanied by audio is when presenting problem solving information. This senior thesis paper analyzed the benefits of using dynamic images when presenting problem solving information to determine whether this is a suitable situation for teaching and whether it ought to be included in the learning design of an educational course.

2.6 Instructional Design

The ability to build a bridge between basic learning research and educational practice has been discussed for a long time. Instructional design is defined as the practice of creating instructional experiences which make the acquisition of knowledge and skill more efficient, effective, and appealing [20].

In a paper published in *Educational Technology*, Merrill and et al [20] argues that instructions ought to be designed based on the learners' knowledge of the subject being taught. Merrill mentions that as people acquire more experience with a given topic, they progress along a low-to-high knowledge continuum. The continuum is as follows:

1. Being able to recognize and apply the standard rules, facts and operations of a profession (knowing what).

2. Thinking like a professional to extrapolate from these general rules to particular problematic cases (knowing how).

3. Developing and testing new forms of understanding and actions when familiar

categories and ways of thinking fail (reflection-in-action).

The instructional design should be created depending on where the learners are on the continuum in terms of their background knowledge in the subject to be taught.

In the experiments conducted in this senior thesis all learners were expected to be classified in the first position on the low-to-high knowledge continuum. All learners are expected to have little to no background knowledge on the subject to be taught. The learners will know what the subject is but they will not know how to complete the tasks given to them. This senior thesis analyzes the effectiveness of presenting information through dynamic images when a learner lies on the first position on the low-to-high knowledge continuum.

2.7 Research of Distance Learning Education

A study published in the *International Review of Research in Open and Distributed Learning* journal by Zawacki-Richter and et al [?] in 2017 reviewed 516 articles over seven separate time periods to determine research trends in distance education research. The seven different time periods that were analyzed were classified as such: professionalization and institutional consolidation (1980-1984), instructional design and educational technology (1985-1989), quality assurance in distance education (1990-1994), student support and early stages of online learning (1995-1999), the emergence of the virtual university (2000-2004), collaborative learning and online interaction patterns (2005-2009), and the interactive learning through massive open online courses and open educational resources(2010-2014).

A second content analysis was conducted on all research articles published in the *International Review of Research in Open and Distributed Learning* journal between 2000 and 2015. The classification of research for the analysis is based on the framework that splits the research areas of distance education into three categories:

1. Macro level: Distance education systems and theories.
2. Meso level: Management, organization, and technology.
3. Micro level: Teaching and learning in distance education.

These three categories are further split into fifteen more specific categories for a more detailed description of the articles published in the journal. The four categories closely related to the research conducted in this senior thesis include:

- Macro level
  - Distance teaching systems and institutions
- Meso level
  - Educational technology
  - Innovation and change
- Micro level
  - Instructional design

There is an apparent interest in the ability to be able to use distance learning as a new effective method of teaching. As seen in table 2.2 between the year 2011 and 2015, instructional design was the most researched area. This demonstrates that researchers are interested in learning how to create instructional experiences that make the acquisition of knowledge and skill more effective, efficient and appealing.

This senior thesis created experiments to further research the topic of instructional design. Establishing concrete evidence that proves that dynamic images are more beneficial than static images when portraying problem solving information gets educational methods one step closer to creating the most efficient instructional design possible.

Distribution of Research Areas From 2000–2015 (N = 580)

Rank	F	Research area
1	103	Instructional design
2	82	Learner characteristics
3	74	Educational technology
4	69	Interaction and communication in learning communities
5	42	Distance teaching systems and institutions
6	41	Professional development and faculty support
7	34	Theories and models
8	29	Access, equity, and ethics
9	27	Quality assurance
10	19	Research methods in distance education and knowledge transfer
11	16	Management and organization
12	12	Costs and benefits
12	12	Learner support services
13	10	Globalization of education and cross-cultural aspects
13	10	Innovation and change
Total	580	

Figure 2.2: A table displaying the distribution of research areas from 2000-2015[?].

Chapter 3

Method of Approach

This chapter of the senior thesis describes the methodology of the rope simulation. It chapter also discusses how the rope simulations were used inside the experiment. Furthermore, this chapter outlines the experiment, describes the process of creating the animations, and discusses the rationale behind the study.

3.1 Knot Tying Simulator Implementation

A knot tying simulation was created with Unity. Unity is an all-in-one editor that supports the development of both 2D and 3D animations. The user interface is a built in system which allows the developer to create user interfaces fast and intuitively. It also has a physics engine which leads the industry in high performance game play [24]. The program created simulates three different animations for tying three different knots. The tool animates a rope from an easy to understand and replicate starting position to the final desired knot. The tool was created to have a simulation of a knot being tied in an easy to follow fashion. These simulations are used in the experiments that are conducted in order to evaluate the effectiveness of information being delivered through dynamic images compared to static images. The complete `RopeController.cs` C# script can be scene in the appendix of this senior thesis.

3.1.1 Key Words

- **GameObject**: The fundamental objects in Unity that represent characters, props and scenery. They do not accomplish much in themselves but they act as containers for Components, which implement the real functionality [25].

- **RigidBody Object**: Enable your GameObjects to act under the control of physics. The Rigidbody can receive forces and torque to make your objects move in a realistic way. Any GameObject must contain a Rigidbody to be influenced by gravity, act under added forces via scripting, or interact with other objects through the physics engine [25].

- **Solver**: The ObiSolver is responsible for simulation particle physics and enforcing constraints. It can be applied to any GameObject in the scene [23].

- **Spline**: A piecewise polynomial parametric curve. Splines are popular curves because of the simplicity of their construction, their ease and accuracy of evaluation, and their capacity to approximate complex shapes through curve fitting and interactive curve design [23].

- **Particle**: A small sphere that can affect other particles. It can also affect and be effected by other objects [23].

- **Vector3**: Used to represent 3D vectors and points. In Unity, it is used to pass 3D positions and directions around [25].

- **Lerp**: Find a point some fraction of the way along a line between two endpoints. Generally used to move an object gradually between two points [25].

3.1.2 Unity: Obi Ropes

Obi is the first CPU-based real time unified physics framework. It provides a unified framework for interactive ropes, advanced editor tools, high performance multi-threaded solver, two-way interaction with rigidbodies, supports all collider types, and allows for low budget, simple effects to extremely complex behavior. Obi Rope is a downloadable asset available in Unity [22].

Obi Rope allows for creation of realistic ropes, with huge control over their look. This asset provides a Spline-based fast rope and chain generation system, procedural rope mesh generation, and zero-stretch rope simulation [23].

Obi Rope is a huge factor in the simulations created for this senior thesis. Without Obi Rope, it would have been much more difficult to create a rope simulation for the demonstrations required to conduct the experiment which is needed to test the hypothesis of this thesis. Ropes are very difficult to simulate in a 3D environment compared to other 3D-Objects. Other 3D-Objects have very distinct edges and joints. To add physics to a cube or sphere, it is possible to calculate where the edges would be located when applying a force. The edges and location are in fixed positions relative to the rest of the object. Ropes, however, are much more difficult to apply physics properties. In order to create a 3D rope that looks and behave the same way an actual rope requires a lot of complex calculations because of the lack of distinct joints and tension. Animating a realistic 3D rope with accurate physical properties, requires calculating how one point in the rope object will affect the rest of the entire rope. Since there are no distinct joints, every single point of the rope will react independently. The only thing keeping the points on the rope connected is through tension. Obi Rope solves this problem with the use of particles.

The Obi Rope asset uses splines to generate the initial shape of the rope as seen in 3.1. The spline has several control points, which are the white points, that can be dragged to different location to form different curves. Once the control points are in the desired locations, then the rope is initialized. Before initializing the rope, there are several different properties of the rope that can be customized.

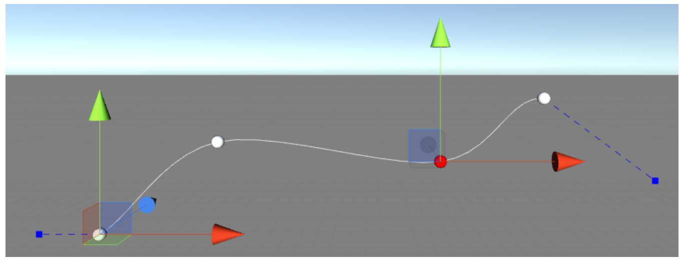


Figure 3.1: Example of creating an Obi Rope using a spline.

One of those properties is the resolution of the rope. When the resolution is either increased or decreased it changes the number of particles in the rope. Figure 3.2 displays the particle editor which allows for each particle to be customized. Figure 3.2 also displays how particles are positioned in the Obi Rope. If the resolution is increased, there will be more particles in the rope. It is important to note that the rope length is not changed, but the density of particles because more particles are added. This changes the proximity of the particles so that they are closer together. Decreasing the resolution has the opposite effect. Furthermore, the particle editor allows the position of specific particles to be locked. This feature was useful to lock the ends of the rope in position. This helped create a scene that is similar to two shoe lace strings coming out of the top holes of a shoe lace.

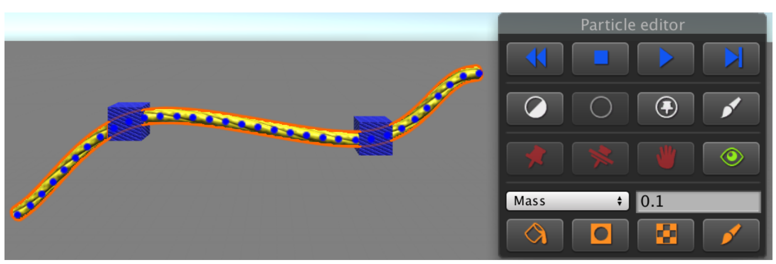


Figure 3.2: Example of particle editor tool in Obi rope.

Another important feature of the particle editor is the ability to pin rigidbodies to specific particles in the Obi Rope. In other words, an object can be attached to a specific location on the rope. This object can then be used to drag the rope by the object. This is important for creating the simulation used in the experiment because to tie the knots, it was necessary to be able to move specific sections of the rope. In Figure 3.2, the blue boxes are examples of different rigidbodies (enlarged) that would be used to drag the rope in different directions. Each rigidbody can be moved independently of each other to drag the rope in any direction. This served a great purpose when creating the simulations of the knots being tied. However, there is no script provided by Unity that will move the rigidbodies. Therefore a C# script was written to move the rigidbodies to the necessary locations.

In Unity, there are two main functions that are used. The first function as scene in Figure 3.3 is the `Start` function. The second function is the `Update` function as seen in Figure 3.4.

The `Start` function's purpose is to initialize all of the components and arrays that are relevant to moving the rigidbody. Lines 5, 6 and 7 of the `Start` function are used to access the first, second, and final waypoints in the waypoint array. Finally, the distance variable is used to get the distance from the where the object is currently located to the way point that the object is moving towards. All of these variables need to be declared and defined before the `Update` function can be called.

The `Update` function is where most of the action occurs. The `Update` function is the most used function in Unity and is called every frame. Inside the `Update` function in the `RopeController.cs` script, there are three if statements which allow for the rigidbodies to move to the way points. The if statement on line 4 checks to see if we have reached the end of the array containing the way points locations. In line 9, the `Vector3.Lerp` function is used to slowly transform the current object closer

```
// Use this for initialization
void Start () {
  startTime = Time.time; //save the current time
  //accessing first, second and final waypoints in waypoint array
  startTransform = waypoints [0];
  endTransform = waypoints [1];
  finalPos = waypoints [waypoints.Length - 1].position;
  //calculating distance between two points
  distance = Vector3.Distance (startTransform.position, endTransform.position);
}
```

Figure 3.3: `StartFunction`: `Start` function in the `RopeController.cs` script

to the final destinations. The second if statement on line 11, is used to check that the object being moved is less than 95 percent of the way towards the destination. If the object is greater than 95 percent of the way towards the destination, then the object's location is updated to the final position. This is a precautionary conditional statement to prevent the object from moving passed the destination. If the object is less than 95 percent of the way towards the destination, then the variables containing the distances, time, and way point locations are all updated. These variables with updated values will be used in the next frame when the `Update` function is called.

The `RopeController.cs` script has a fairly simple reaction with the scripts provided by the ObiRope asset. As seen in Figure 3.5, the `RopeController.cs` script is called when the Unity editor begins simulating the animation. When the `RopeController.cs` is called, then the `ObiRigidBody.cs` script gets called because the `RopeController.cs` is updating the position of the rigidbodies. When the rigidbodies moves, which are attached to the ObiRopes, it begins to drag the ObiRope in the direction that the rigidbodies. This calls on the `ObiRope.cs` script because the physics and positions

```
// Update is called once per frame
void Update () {
  //check to see if reached end of waypoint array
  if (currentIndex < waypoints.Length) {
    //calculate distance covered and distance left
    float distanceCovered = (Time.time - startTime) * speed;
    float fracJourney = distanceCovered / distance;
    //move the rigidbody slowly along the line between the two
        points
    transform.position = Vector3.Lerp (startTransform.position,
        endTransform.position, fracJourney);

    if (fracJourney > 0.95f) { //check if travelled 95 % to
        finaldestination
      currentIndex++; //update index

      //check if 2 or more waypoints left in array
      if (currentIndex < waypoints.Length - 1) {
        startTime = Time.time; //get time
        //get new start and end waypoints
        startTransform = waypoints [currentIndex];
        endTransform = waypoints [currentIndex + 1];
        //calculate distance between waypoints
        distance = Vector3.Distance (startTransform.position,
            endTransform.position);
      }
    }
  } else {
    //move rigidbody to waypoint
    transform.position = finalPos;
  }
 }
}
```


Figure 3.4: `UpdateFunction`: Update function in the `RopeController.cs script`

of the ropes must be updated. This is essentially how the ObiRopes were animated and how the `RopeController.cs` is connected to the other scripts provided by the ObiRope asset.

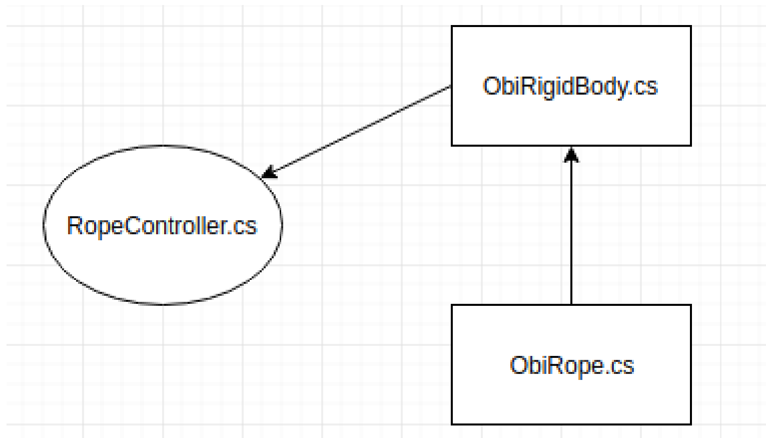


Figure 3.5: Flowchart of scripts dependent on `RopeController.cs`.

3.1.2.1 Reef Knot

The Reef Knot, also known as a Square Knot, is a very simple knot. The steps and freeze frames that were used during the creation of the Reef Knot animations were selected from Ian's Shoelace website [12]. This knot was selected as one of the three knots to be animated and shown as a demonstration because it was simple knot to begin learning how to animate the knots and it would serve as a warm-up for the participants watching the demonstration. The participants would be able to get more comfortable with the demonstrations being shown to them before moving onto more complicated knots. Figure **??** shows the steps required to tie the Reef Knot. These steps are also the freeze frames used in both the static and dynamic demonstrations. Even though the Reef Knot is very simple, it serves a purpose to show that either method can provide enough information for the participants to complete the knot.

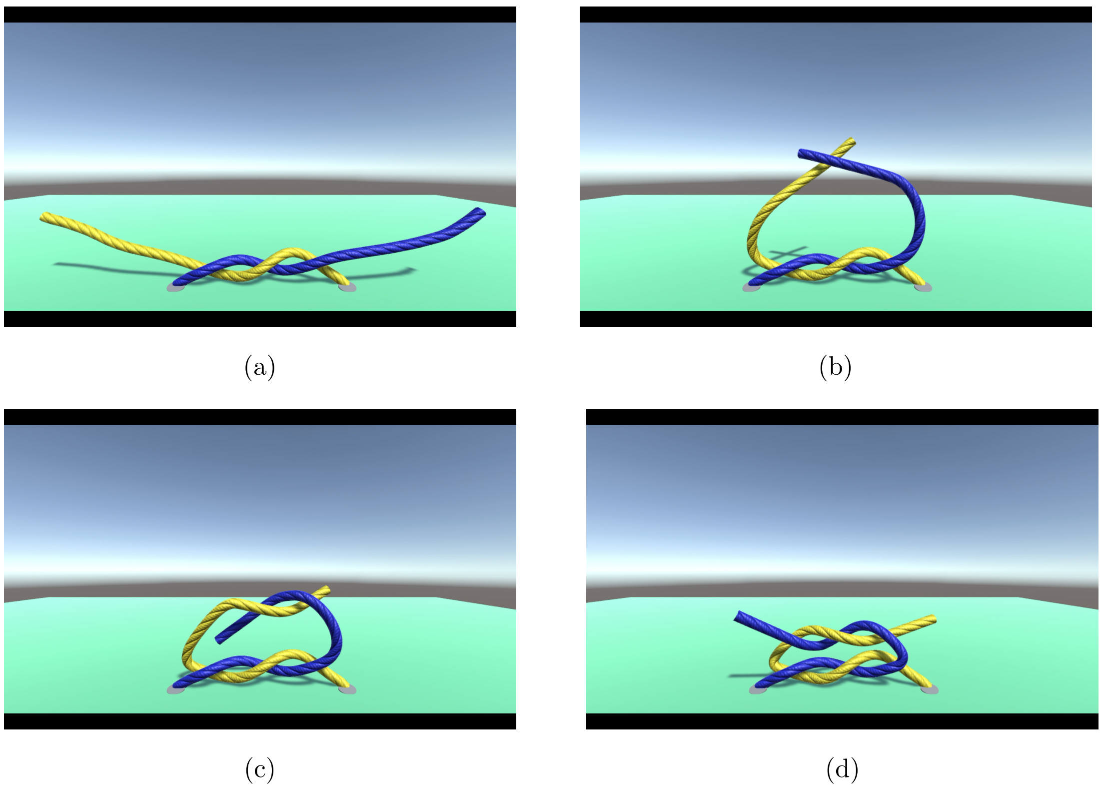

(a) (b) (c) (d)

Figure 3.6: Steps to tie Reef Knot

3.1.2.2 Crossed Ian's Knot

The Crossed Ian's Knot is a twist on the most popular shoelace knot from Ian's Shoelace website [12]. The steps and descriptions to tie this knot were slightly altered from the steps seen on Ian's Shoelace website to go along with the animations. This knot was meant to be the second hardest knot to tie out of the three knots. Figure **??** shows the steps required to tie Ian's Crossed Knot. These steps are also the freeze frames used in both the static and dynamic demonstrations.

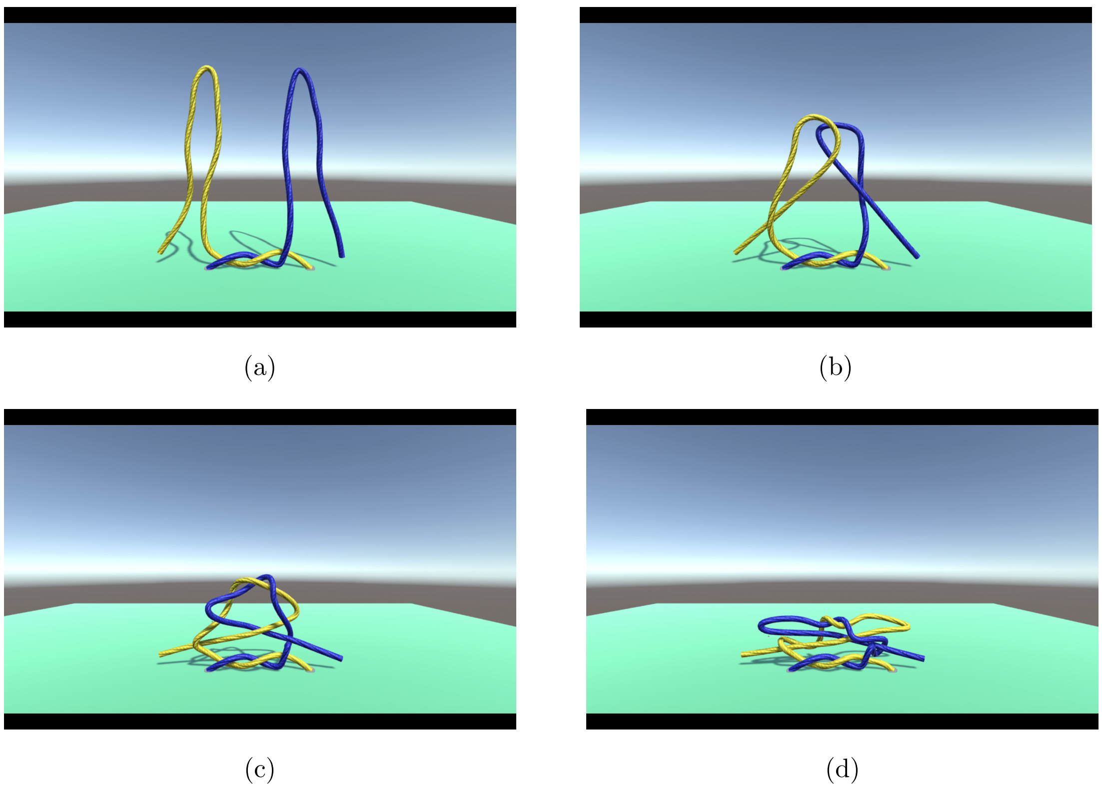
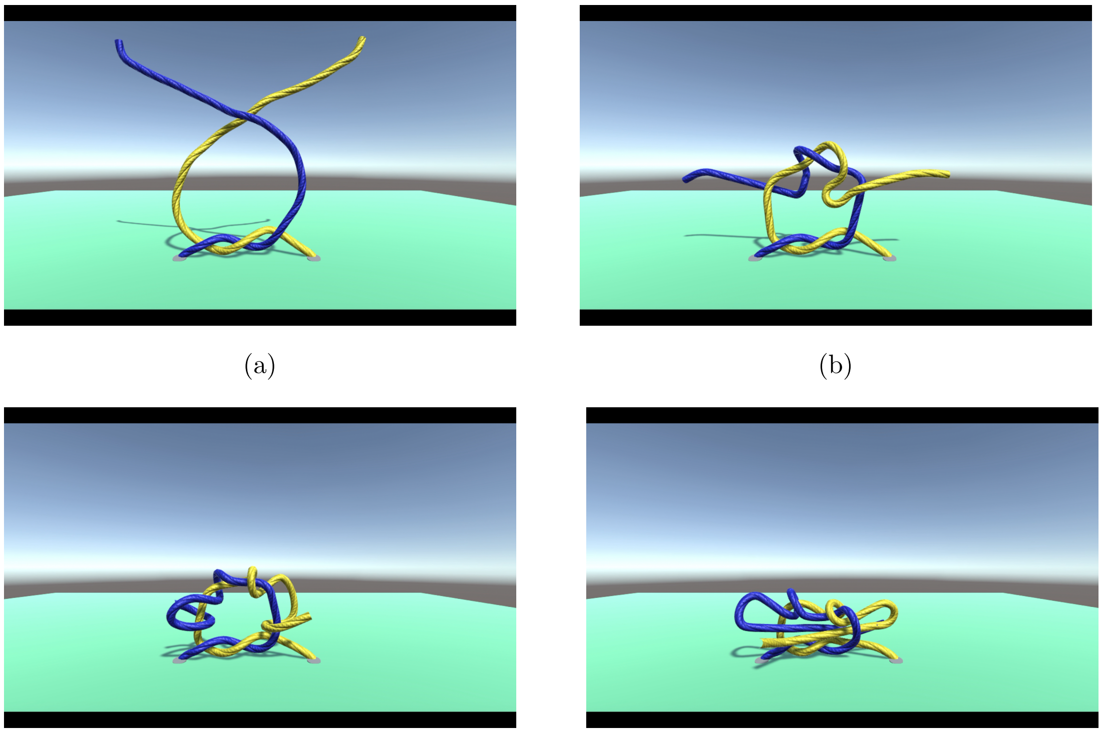


Figure 3.7: Steps to tie Ian's Crossed Knot

3.1.2.3 Freedom Knot

Freedom Knot is a secure knot also located on Ian's Shoelace website [12]. The steps and descriptions to tie this knot were slightly altered from the steps seen on Ian's Shoelace website to go along with the animations. This knot was meant to be the hardest knot to tie out of the three knots. Figure **??** shows the steps required to tie the Freedom Knot. These steps are also the freeze frames used in both the static and dynamic demonstrations.



(a) (b) (c) (d)

Figure 3.8: Steps to tie Freedom Knot

3.2 Data Generation

This section discusses the what experiments were setup to test the hypothesis of this thesis, the rational behind the tests and setup, and the final experiment design used to conduct the study.

3.2.1 Methodology

In order to test the hypothesis that dynamic images would aid humans in problem solving more quickly than static images, it was important to limit as many variables as possible. It is also beneficial to create an experiment that would be quick and easy for students to participate in to encourage more students to partake in the study. It is significant that any person could watch the demonstration and then learn how to tie the knot with only the demonstration and no other additional help or resources. Furthermore, if the demonstrations were capable of being used to learn how to tie the knots from anywhere in the world then the idea of distance learning can also be evaluated.

However, for the particular study conducted, the participants were monitored and were not delivered the demonstrations from distant and asked to complete the knot. It was important to be able to accurately record the time to completion of tying the knot because this study was designed to compare the times between participants who watched the demonstration static images and participants who watched the demonstration with dynamic images.

3.2.2 Experiment Design

- **Location**: One of the Alden Hall computer labs (Alden 101 or Alden 109).
- **Duration**: 25 minutes maximum.
- **Procedure**

  1. Each computer station was set up identically, but had one of two versions of demonstrations to be watched. The demonstrations had dynamic images or static images in order to provide the knot tying information. Both versions had an audio narration.

2. Participants were randomly assigned to one of the available computer stations. Participants were asked to watch 3 separate demonstrations, one at a time, which was displayed at the workstations. They had the ability to rewatch the demonstration as many times as desired.

3. While watching each demonstration, the participant were asked to recreate the knot that was being displayed to them on the screen. They were allowed five minutes to tie the knot. If they were unable to complete the knot, then a time of five minutes was recorded.

4. The time (in seconds) to tie each knot was recorded using a stopwatch. The timer started when the participants hit the play button on the video.

5. The data was entered as Participant #: Knot 1 time, Knot 2 time, Knot 3 time. None of the names of the participants were recorded.

6. After all experiments have been completed, the data was be separated into two groups: students who watched the demonstration using static images and the students who watched the demonstration using dynamic images.

How each station was setup can be seen later in this chapter in section 3.3.2.

3.2.2.1 Rationale

The final demonstrations that were used in the experiment included two separate versions of knots being tied paired with explanatory verbal narration. The reasoning behind comparing a static image paired with audio and a dynamic version paired with audio was previously discussed in Chapter 2 Section 2.3. In Lawrence's paper [21], he includes a Figure 2.1 suggesting that the best way to present problem solving information to be learned is with an animation with explanatory verbal narration. The inspiration for creating two demonstrations with audio came from Figure 2.1.

The static image demonstration was also paired with audio to limit the number of variables in the experiment. Otherwise, the results could have been affected by the additional audio and not just the dynamic images instead of the static images. Both versions of the demonstrations use the same freeze frames in order to keep as many variables as similar as possible. This was also to prevent giving one demonstration an advantage over the other. Furthermore, the demonstrations are the same length and the audio for both demonstrations are exactly the same. Both demonstrations were uploaded to `www.Youtube.com` to signify that distance learning would be possible and demonstrate the feasibility of providing information with animations through distance learning. Anyone in the world could now watch the video and learn the same way the participants did in the experiment. This is how the participants watched the experiments. However, the participants were monitored during the experiment whereas people learning from distance would not be monitored and would not have the same setup as the participants in the experiment. But it is worth noting that, it is still possible for anyone to watch the videos and potentially learn how to tie the knots.

3.2.2.2 Audio Narration

Three separate audio files were recorded using iMovie [2]. Some pauses were incorporated in between steps to allow the participant to process the problem solving information that they received.They were then paired up with the corresponding knots. The steps that were narrated for the animations were altered steps from Ian's Shoelace website [12]. The audio narrations were the exact same for both versions of the knots.

3.2.2.3 Dynamic Version

The dynamic version was recorded by using the QuickTime [3] screen capture feature. Unity provides animation of the scenes created and using various scripts allows for control over the animations. When the animation began, the section of the screen displaying the animations was capture using the screen capture. This video that was captured was then imported into iMovie [2]. The audio previously created was also imported and aligned with the video. After completing the dynamic version of all the demonstrations, they were uploaded to `www.Youtube.com`

3.2.2.4 Static Version

The static images displaying the steps were not taken from Ian's Shoelace website because the demonstrations needed to look as similar as possible. Had the static images been taken from the website then the dynamic and static images would have looked different which could have been a potential threat to the validity of the study.

3.3 Data Collection

3.3.1 Participation

Participants were selected from students at Allegheny college who are 18 years or older. 22 students participated in the experiment. Out of the 22 students, 4 of those students had background knowledge of knot tying. The 18 students without any background knowledge of knot tying, beyond tying shoes, were split into two groups of 9 each. One group was shown the control demonstration, which used the static images, and the other group was shown the experimental demonstration using the dynamic images. The 4 students who did have background knowledge were also split up into each group.

3.3.2 Setup

Each station was set up with two strings that were 24.5 inches long. One of the strings was blue and one of the strings was yellow to match the demonstrations. The blue string was taped down on the right side and the yellow rope was taped down on the left side. They were taped down approximately 2 inches apart in front of the computer being used to view the demonstrations.

Chapter 4

Experimental Results and Analysis

This chapter of the senior thesis presents the results of the study. It chapter also describes the data tables and charts used to present the results. Furthermore, the results are analyzed and any significant data is identified and discussed. Finally, the potential threats to the validity are considered.

4.1 Research Problem

The ability to easily and quickly express ideas through images has been a major element in teaching since the ability to create multimedia started. In order to evaluate which method aids humans in the speed of understanding of a new concept and applying the new concept in order to complete a task, this paper presents a study of the effect of human comprehension between dynamic images and static images. These animations will be evaluated against static frames of the animation to compare which form of teaching (static images or dynamic images) a new theory supports the ability for the participant to comprehend the new information in order to complete the given task more quickly. The task completed by the participants in this study was tying a new, unknown knot.

4.2 Results

22 students participated in the experiment. Out of the 22 students, 4 of those students had background knowledge of knot tying. The 18 students without any background knowledge of knot tying, beyond tying shoes, were randomly split into two groups to allow for even distribution across participants watching each version of the demonstration. Each student attempted to tie three separate knots and the time to completion of each knot was recorded. The data from each participant was inputed into Table 4.1 of three different section for each knot. When a student was unable to complete the knot within the time limit then 300 seconds was recorded signifying that they hit the time limit.

The results were not inputed in the order of the participants partaking in the study but it was organized in increasing order into the data table for both the static version and the dynamic version. The purpose of ordering the data in increasing order was to create a data table that more effectively displayed the time to knot completion. The rows do not directly correlate to each other. It is important to note that each row contains data for two separate participants. The static column represents one participant and the dynamic represents another participant. This allows for quick comparison between the two groups for each knot. The numbers in the table that appear with an asterisk represents the four students that had previous experience in knot tying.

Two more data tables were created to display the average time and the standard deviation of each version of the demonstration for each knot tied. See Table 4.2 and Table 4.3. In Table 4.3, the row for participants with background knowledge could not be calculated because there were only two data points for each version. The standard deviation function requires atleast 3 data points to properly calculate the standard deviation.

Table 4.1: Time to Knot Completion (seconds)

Reef Knot		**Crossed Knot**		**Freedom Knot**	
Static	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**
35*	35*	120*	57*	70*	50*
35*	35*	133*	88*	80*	54*
35	35	147	98	113	104
35	35	150	113	140	120
35	35	224	120	200	140
35	35	280	152	203	146
35	35	300	254	216	152
35	35	300	300	280	160
35	35	300	300	280	192
45	35	300	300	284	194
72	35	300	300	300	200

Figure 4.1 is a boxplot graph used to help visualize the results between the two groups; the control group and experimental group. A boxplot is a method for graphically depicting groups of numerical data through their quartiles. Boxplots may also have lines extending vertically from the boxes indicating variability outside the upper and lower quartiles. The boxplots created for the reef knot appear to be a line with two outlining data points. The line in the middle of the boxplot indicates the mean value of the data. This occurred because of the simplicity of the knot and the almost identical times to complete the Reef Knot.

Figure 4.1: Boxplot Graph of Time of Knot Tying

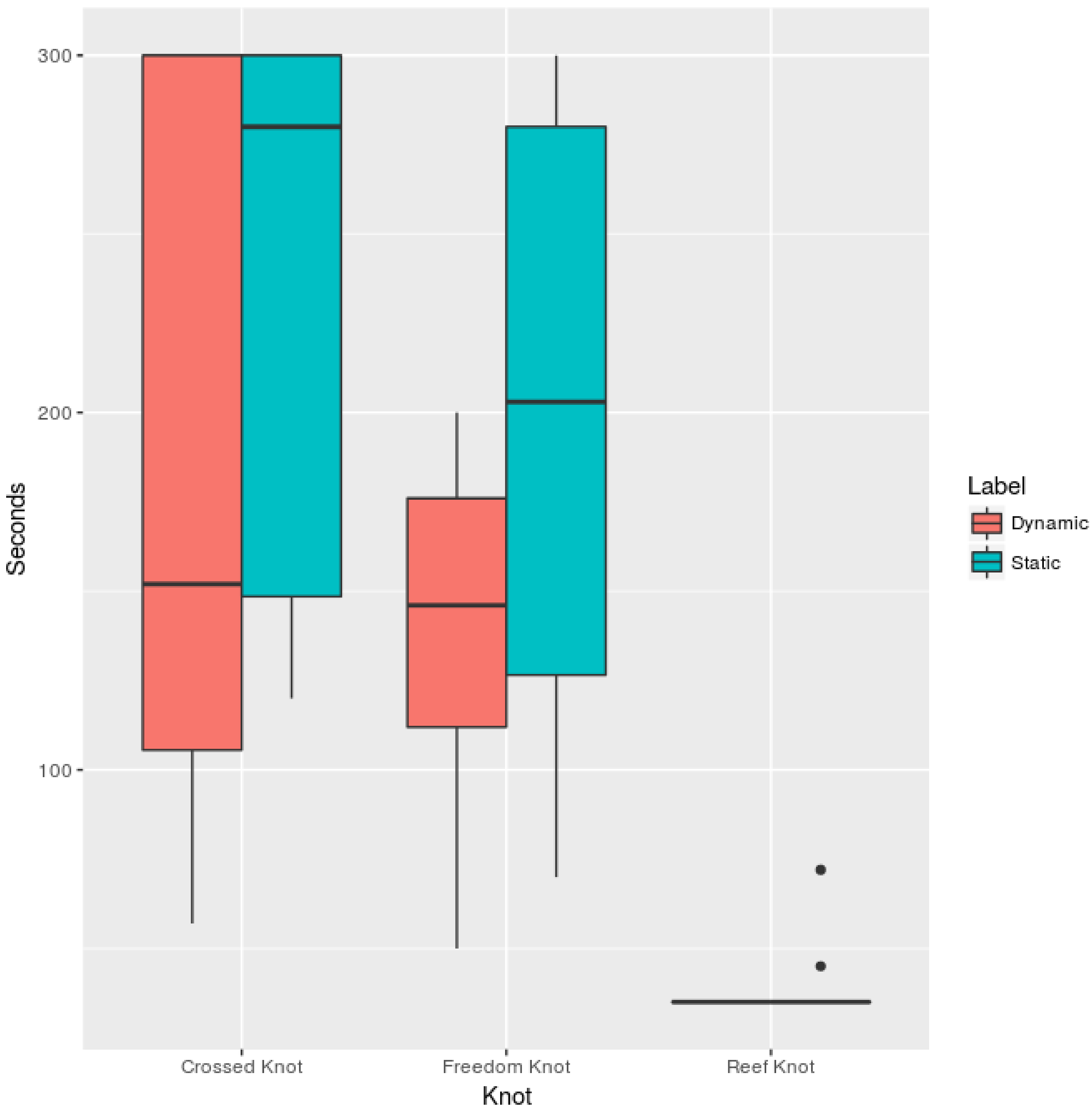


Table 4.2: Average Time to Knot Completion (seconds)

	Reef Knot		Crossed Knot		Freedom Knot	
Participants	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**
All participants	39.27	35	232.18	189.27	196.91	137.45
No background knowledge	40.22	35	255.67	215.67	224	156.44
Background knowledge	35	35	126.50	72.5	75	52

Table 4.3: Standard of Deviation Time to Knot Completion (seconds)

	Reef Knot		Crossed Knot		Freedom Knot	
Participants	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**
All participants	11.26	0.0	78.60	100.66	85.14	51.89
No Background knowledge	12.37	0.0	65.57	67.18	67.18	33.66
Background knowledge	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*

4.3 Analysis

Upon reviewing the results from Table 4.1 and Table 4.2, the experiment conducted indicates that there appears to be an advantage to using the dynamic image method to present problem solving information over static image method. On average, the group that received the dynamic version of the demonstration completed the knots in a faster time than the group that received the static version of the demonstration. To calculate exactly how much faster the dynamic participants were, the following formula was used: $\% = (s - d) * 100$ where s is the average time completion of the students who watched the static versions of the visuals and d is the average time of completion for the students who watched the dynamic versions of the visuals. Using this formula, the following analysis about the average time to completion of each group can be established:

- **Reef Knot**: The dynamic group was able to tie the Reef Knot 112% faster than the static group when all participants were considered. When excluding the participants that had previous knowledge of knot tying, the percentage increased for the dynamic group's ability to tie the knot at 114% faster than the static group. However, when looking at just the participants that had background knowledge in knot tying, the groups performed at the same level.

- **Crossed Knot**: The dynamic group was able to tie the Crossed Knot 112% faster than the static group when all participants were considered. When excluding the participants that had previous knowledge of knot tying, the percentage increased for the dynamic group's ability to tie the knot at 118% faster than the static group. However, when looking at just the participants that had background knowledge in knot tying, the static group performed 103% faster than the dynamic group.

- **Freedom Knot**: The dynamic group was able to tie the Freedom Knot 143% faster than the static group when all participants were considered. When excluding the participants that had previous knowledge of knot tying, the percentage increased for the dynamic group's ability to tie the knot at 143% faster than the static group. When looking at just the participants that had background knowledge in knot tying, the static group performed 144% faster than the dynamic group.

In every case except the participants with background knowledge tying the Crossed Knot, the dynamic image method of the animation proved to be more effective. There was an increase in the speed to tie the knots when the participants were shown the dynamic version. According to this current data and this sample size the dynamic versions were, overall, a more effective way to provide the problem solving information. When the participants who had background information were taken out of the equation, an increase in the average speed to tie the knot can be seen by the dynamic group. This is significant because it suggests that when the information is newer or the participants are less comfortable with a subject, that the dynamic method proved to have been a more effective way to deliver information. However, the increase in speed was only significant with the Freedom Knot with the dynamic group on average being 143% faster than the static group. Examining the results of the other knots, there is an increase in speed, but the increase is not by a large factor. This data suggests that the dynamic image method is more effective than the static image method, but not always significantly better.

It is also worth noting that upon examining Table 4.3, the standard deviation was very large for both the Crossed Knot and the Freedom Knot. This is important because it signifies that there was a large variation of completion times, which can be seen in Table 4.1. A much larger sample size would be necessary in order to make a more concrete argument for one method over another. This will be discussed further in Section 4.4.

4.4 Potential Threats to Validity

When examining the data of the Reef Knot, it can be seen that 20 out of 22 participants all completed the knot in 35 seconds. This is due to the fact that all 20 participants finished the knot exactly when the demonstration was over. The other 2 participants had to rewatch the demonstration one more time in order to complete the knot. The Reef Knot was a very simple knot to complete, therefore it is not surprising that the 20 participants all completed the knot the first time watching the demonstrations. Consequently, the results for the Reef Knot does not provide great benefit to the argument of whether the dynamic image method are more effective than static image method.

There are several potential threats to validity that are worth mentioning. There were some threats that were a result of time constraints, a few threats due to the creation of the demonstrations, and a few threats that were unavoidable given what the purpose of the study is. These threats could have either changed the outcome of the experiment or could have unintentionally provided one method an advantage over another.

- **Small Sample Size**
  - The number of students that partook in the experiment was not large. In order to have more conclusive and accurate data, a much greater scale of participants would be needed. Although, the data collected appears to support the idea that the dynamic method is more effective, more experiments on more humans needs to be conducted.
- **Audio Narration**
  - The same audio was used for both versions of the demonstrations to decrease variability but, there are several things to consider when reviewing the audio narration. Does the audio pair well with the animations? Should the narration have occurred before the animations began? Did the audio accurately describe what the animations and static images were doing? Was the audio clear and easy to hear? All of these could have had a potential factor in the outcome of the experiment results.
- **Number of Knots**
  - Were there enough knots in the experiment to draw conclusive evidence to show which method was more effective at presenting the information?

Since the Reef Knot was very simple, it does not provide beneficial results to the experiment besides that it is very possible to teach the knots with either method. The results would be more notable if there were more knots for participants to tie.

- **Time Limit**
  - There are two main factors that could have had an effect on the outcome data collected. When the participants were unable to complete a knot within the time limit, the time limit was recorded as the time to completion. The rationale behind this was to provide some sort of numeric value that could be included in the statistical analysis of the results. However, this has an effect on the data because it does provide the most accurate evaluation of the participants ability to tie the knot. In order to have the best data to support either method, it is best to get the most accurate time of completion recorded. This leads to the second factor that can be identified as a potential threat, should the participants have been given more than five minutes to complete the knot? Would this have lead to getting more a more accurate representation of the effectiveness of the methods or would giving more time to the participants have concluded similar results?
- **Higher Quality Demonstrations**
  - 45% of the participants that were shown the static version of the Crossed Knot were unable to tie the knot within the time constraint. Does this mean that the static version was not of high quality meaning it did not effectively provide the information required to tie the knot or was the knot too difficult to learn how to tie with these methods in the time constraint? When examining Table 4.1, it is evident that the demonstration of the

Crossed Knot resulted in the most participants unable to complete the knot within the time for both methods. It is worth considering whether the knot was too difficult or whether the Crossed Knot demonstration should have been a higher quality. Perhaps, the demonstration of the Crossed Knots could have included more freeze-frames or had longer pauses after the narration and in between the animations.

Chapter 5

Discussion and Future Work

This chapter provides a summary of the experimental results, states the significance of the findings, discusses possible future works and mentions additional notes.

5.1 Summary of Results

A discussion of the significance of the results and a review of claims and contributions.

The results of this study is that the dynamic versions were, overall, a more effective way to provide the problem solving information. According to the experimental results, the answer to the question, ”Is it more beneficial to show humans static images or dynamic images when when attempting to provide new problem solving information?”, is using dynamic images. This is significant because this suggests more research should be conducted to make a concrete claim on which method is better, the dynamic image method vs the static image method. Assuming the dynamic method is better, then it is important to begin reevaluating the way that humans are being taught information. It is important to be using the most effective system to educate society since education has a large impact on the outcome of society and the advancements of technology. Another significant result of this study is that there are effective methods to teach humans over distance. This is evident because this study created demonstrations of knots that were capable of teaching humans without any additional help. Even though the humans were monitored to record the results, it is possible for people to learn the information necessary to tie the knots without any human interaction. This is significant because this is evidence that humans can be taught from a large distance. This study suggests the distance learning is not only capable but also effective.

To relate this back to the large impact of sports, this study suggests that it would be more beneficial to begin using animations to provide athletes with knew information such as new plays or strategies.

5.2 Future Work

There are many different variations of the experiment used in this study that would have been interesting to see the results.

- **Static Images then Dynamic Images**
  - After one participant was unable to tie the knot when shown the static version of the demonstration for that knot, they were presented the dynamic version of the demonstration and then were able to tie the knot. This provides a variation of the study not originally anticipated: Would a participant, if unable to tie the knot after being shown the static version of the demonstration, be able to tie the knot after being shown the dynamic version?
  - Another variation of the experiment discusses above is can a participant shown both versions of the demonstration complete the animation quicker than a participant only shown one version?
- **Changes in Audio**

- Upon monitoring the participants, it was noted that sometimes the participant had a difficult time paying attention to the audio narration, watching the animation, and trying to tie the knot. This lead to the the idea to test whether audio was beneficial in the demonstration. If one version of the dynamic demonstration included the audio narration and the other version did not have audio, which demonstration would result in a faster completion time of tying the knots?
- Another variation of the experiment discussed above could be: If one version of the dynamic demonstration included the audio narration while the knot was being animated and the other version had audio narration before the knot was animated, which demonstration would result in a faster completion time of tying the knots?
- A third variation of the experiment could be one version of the demonstration uses audio narration and the other version uses textual narration.

- **Preliminary Viewing of Demonstration**
  - Several times during the experiment, it was noted that the participants would not reach the end of the demonstration and would get stuck trying to figure out a specific step in the knot tying process. Would it have been more beneficial to have the participants watch the demonstration one time through before attempting to tie the knot?

- **Length of String in Setup**
  - One issue that caused participants problems tying the knot unbeknownst to them, was that they were trying to tie the knot too high up on the strings provided. Although, there was plenty of string available to the tie

the knot, would it have been beneficial to have provided a larger string to decrease the difficulty of tying the knots?

These are all variations of the experiment conducted in this study that were considered after completing the experiment. The results of all these experiments would be intriguing and could, perhaps, provide a better understanding of the best method of providing problem solving information.

There are plans in the future to "clean up" the current animations to make the animations easier to follow along with and understand what is happening inside the animations. Other future works are creating more knots in Unity or in another programming environment.

5.3 Additional Notes

5.3.1 Processing: What went wrong?

Processing the original method of creating the animations required for the demonstrations. However, it was much more difficult to create 2D or 3D animations of knots being tied. Processing is a sketchbook language and after many attempts, it became apparent that using the Unity physics engine would be a quicker and more practical method of creating the animations. Therefore, development of the animations shifted from Processing to Unity.

5.3.2 Time to complete animations

A related point to consider is the time it took to create the animations required in the demonstrations used to provide participants with the information. The animations together took over 30 hours to complete. There is a significant learning curve to create the animations the way they were created for the experiment in this paper.

It is important to consider whether the effectiveness of dynamic images is significant enough to invest a large quantity of time to make the dynamic images. Further tests would need to be conducted to have a more concrete answer to this dilemma but this paper is a step forward in that direction.

Appendix A

Java Code

The repository containing the Unity Project that was used to create the animations for this senior thesis is located at `https://github.com/milleriAC/seniorthesis/`. The instructions on how to download, setup, and use the system can also be found in `README.md` in the repository.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using Obi;

public class MoveDemo : MonoBehaviour {

  //initalizing all necessary variables
  private Transform startTransform, endTransform;
  public Transform[] waypoints;
  public float speed;
  Vector3 startPos;
  private Vector3 finalPos;
  private float startTime;
  private float distance;
  private int currentIndex = 0;

```

```

// Use this for initialization
void Start () {
  startTime = Time.time; //save the current time
  //accessing first, second and final waypoints in waypoint array
  startTransform = waypoints [0];
  endTransform = waypoints [1];
  finalPos = waypoints [waypoints.Length - 1].position;
  //calculating distance between two points
  distance = Vector3.Distance (startTransform.position,
     endTransform.position);
}

// Update is called once per frame
void Update () {
  //check to see if reached end of waypoint array
  if (currentIndex < waypoints.Length) {
    //calculate distance covered and distance left
    float distanceCovered = (Time.time - startTime) * speed;
    float fracJourney = distanceCovered / distance;
    //move the rigidbody slowly along the line between the two
       points
    transform.position = Vector3.Lerp (startTransform.position,
       endTransform.position, fracJourney);

    if (fracJourney > 0.95f) { //check if travelled 95 % to
       finaldestination
      currentIndex++; //update index

      //check if 2 or more waypoints left in array
      if (currentIndex < waypoints.Length - 1) {
        startTime = Time.time; //get time
```

```
            //get new start and end waypoints
            startTransform = waypoints [currentIndex];
            endTransform = waypoints [currentIndex + 1];
            //calculate distance between waypoints
            distance = Vector3.Distance (startTransform.position,
                endTransform.position);
          }
        }
      } else {
        //move rigidbody to waypoint
        transform.position = finalPos;
      }
    }
}
```

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