# Animation of Induction Principles Through the World Wide Web

An Interactive Qualifying Project Report

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by

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# Abstract

Mathematical induction is an important concept that many students have difficulty understanding. This project attempts to improve comprehension of induction by using animations of induction presented through the World Wide Web to supplement course curriculum. An interface was created to present such material over the Web without requiring students to obtain special software for viewing. Learning styles of the students are also considered, although little correlation can be made between efficacy of the animations and any particular learning style.

# Acknowledgements

I would like to thank my fiancé Jennifer for supporting me in completing these final degree requirements, for mercilessly editing parts that completely lacked organization, for the wealth of information she provided regarding formatting and references, and for always being there for me.

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## Executive Summary


In a world of constantly evolving technology, education must similarly evolve to incorporate new techniques into developing curriculum. The Internet has created new possibilities in education from distance learning to assistance during lectures. The psychological community has developed tools to apply new technologies to students as effectively as possible, providing learning style classifications that can detail the strengths and weaknesses of a student. This project uses multimedia over the Internet to teach the mathematical principle of Induction to undergraduate level college students in a graphical manner in order to appeal to diverse learning styles.

Learning modalities were considered to identify those students who might strongly benefit from a multimedia presentation. These include the Visual/Verbal, Visual/Non-Verbal, Auditory, and Kinesthetic styles. Each participating student was surveyed to determine his or her dominant learning style or styles.

While a good deal of research is available on the topic of algorithm animation, few studies have considered animating mathematical proofs. Work on animating algorithms is still quite useful in producing a proof animation because many proofs can be divided into individual steps, creating a sort of algorithm. This approach allows similar techniques to be used when animating proofs and algorithms.

The real-world application of dominos was chosen to identify induction with a common, physical concept in hopes that more students would understand induction if it were presented in a less theoretical setting. This also made it easier to present animated

images, as concepts can be difficult to graphically illustrate.

Results of student evaluations of the produced animated presentation revealed that most students found it helpful in understanding induction. The evaluations also provided useful feedback for modifying and enhancing the interface used to present the material. No significant correlation could be made between students who benefit from the animation and their measured dominant learning styles.

# 1. Introduction

Mathematical induction has proved to be a difficult concept for computer science students to understand. Teaching induction can be particularly challenging, especially over the Internet, which provides no physical interaction between students and the teacher. Visual presentations such as charts and illustrations have been helpful, but can only augment an explanation of induction because they are static. As technology advances, it can provide more efficient methods for communicating to students along various learning channels.

Students learn most effectively through learning channels that correspond to their dominant learning style. Such channels include lecturing, graphics, and printed text. Educators can reach students more effectively by presenting information through more than one channel, thus increasing the probability that the material will target the dominant learning style of any individual student.

Computer animation is a technology rich medium that incorporates many such learning channels. Graphics, written text, audio, interaction, and motion can make animation an ideal tool while providing an interesting environment to hold the attention of students. Other technological advances, such as the Internet, can further enhance the benefits of animations. By incorporating animations into web pages educators can make them available to students while in the laboratory or at home. In addition, many educators are using computers that display web pages through projectors during lectures, making it possible to use animations in class.

This paper examines the use of animations to teach and enforce the concepts of induction and specific induction proofs. This idea has received very little attention in the computer science world, a field where educators typically have competent computer skills that allow technology to be used as an integral tool in their courses. It should be a natural progression for these educators to embrace the new technology of animation, which can add variety and efficacy to teaching.

# 2. Background

In the modern classroom environment, the type and quality of information is no longer the primary concern. How material is presented to students is of increasing importance, particularly with the emergence of online courses. Classification systems become very important in this study of information presentation.

## 2.1 Learning Styles

Many classification devices have been created in the attempt to classify individual people. Some sort based on personality, ranking dominant and recessive traits. Some define the way people interact with their environment. Others classify learning styles and suggest trends between education techniques and specific styles. The four main classifications for learning styles used for this paper are visual/verbal, visual/non-verbal, auditory, and kinesthetic (Jester).

One study divides a common classroom of students into 25-30% visual (verbal and non-verbal combined), 25-30% auditory, 15% kinesthetic, and 25-30% mixed styles (facultyweb.cortland.edu).

### *2.1.1 visual/verbal*

Visual/verbal style students learn best from visual materials with written text. Outlines and written text on blackboards help these students, and they also benefit from textbooks and class notes. These students can often recall material by visualizing it in written form. Diagrams and illustrations are more useful when translated into a written version (Jester).

### *2.1.2 visual/non-verbal*

Visual/non-verbal styles also benefit from materials presented in visual format, but without written text. Diagrams, pictures, and other graphical forms of information help these students the most. A suggested mnemonic device for the visual/non-verbal learner is to create flashcards with a picture or other visual representation that the student can use to associate with specific information (Jester).

### *2.1.3 auditory*

Auditory learners, also categorized as auditory/verbal, learn best from material presented in spoken language format. Lectures, the most common presentation method in most college courses, are best suited for these students.  Books on audiotape are another suitable method for auditory learners. They benefit from talking to themselves and can recall information by 'hearing' it in their head (Jester).

College classrooms have traditionally been dominated by the lecture format. Unfortunately, this form places some students at a disadvantage because it only favors auditory learners (Ross and Schulz, 1999).

### *2.1.4 kinesthetic*

Kinesthetic learners prefer to physically interact while learning. Laboratory sessions are a good technique for this, as are models, flashcards, and demonstrations. These students can best learn from other techniques such as lectures or textbooks if they are simultaneously engaged in some physical activity (Jester).

### *2.1.5 Overconfidence in Students*

Overconfidence is a common problem when dealing with human memory. Commonly people are too confident in their ability to recall a certain fact or idea, or even a certain phrase in a multiple-choice question. Many students learn new material only once, believing this will be sufficient for recall on an exam. This is typically not the case, as the ability to recall memories strengthens with repeated exposure to the material (Matlin, 2005).

Overconfidence can be increased by a "feeling of knowing", or "the prediction about whether you could correctly recognize the correct answer to a question" (Matlin, 2005, p.200). Such a strong feeling may cause students to skip a certain topic in review for an exam because they incorrectly believe they have an appropriate understanding of the topic (Matlin, 2005).

Various strategies can reduce the probability of overconfidence of material. Taking a pretest before an exam can identify areas that require more studying. Another method is to paraphrase a passage several minutes after having read it. This enhances the strength of that particular memory, increasing the chance that it can be recalled when needed (Matlin, 2005).

## 2.2 Animations in Algorithms

Animations and other forms of visual representation have been used to enrich computer science curricula, and the practice is gaining momentum. Most studies agree that animations provide some welcome variety to the normal lecturing method, although it may not provide additional content understanding (Jarc & Feldman, 1998)(Stasko, Badre & Lewis, 1993). Students who have participated in such studies comment that animations made the material more interesting. One study suggested that universities must continue to evolve their teaching process to include web-based multimedia to stay competitive on the educational market (Syrjakow, Szezerbicka & Berdux, 2000).

The development of the field of computer science has progressed rapidly in the last several decades, along with the rise of cheap PCs, the Internet, and Computer science as a profession. The results of studies based on this field have also changed. An empirical study done in 1993 concluded that methods available at the time did not have a significant effect on the comprehension of students in a "Fundamental Algorithms" course (Stasko et al, 1993). Another study in 1998 produced the same results in a data structures course (Jarc & Feldman, 1998).

As software developed, so did the benefits of visual presentation. A more controlled study in 2003 involved lab experiments using web-based software to present animations and other visual representations of material to students. Student comprehension of the material was measured before and after the labs, with significantly increased student understanding after the labs. A more universal approach was taken, using HTML with embedded Java and JavaScript, which is viewable on most browsers (Cordova, 2003).

Another study in 2004 also concluded that animations were of significant educational benefit. Several animations were presented through a course website to students of a graduate-level compilers course. Surveys of the students before and after use of the animations concluded a positive change in comprehension (Jamin, 2004).

## 2.3 Visualizations of Proofs

Many studies chart the progress of animated algorithms. However, far fewer attempts at animating proofs have been documented. Induction is a common method used in many proofs in computer science theory, but many students find it difficult to grasp. A visual representation of certain proofs to either illustrate or replace induction could prove very useful (Goodrich & Tamassia, 1998).

Using visualizations of proofs to teach fresh material to students presents problems because the proof cannot be transformed into an example. If sample values are entered to aid in illustrating parts of the proof, it becomes an example and can no longer be used to teach the proof itself. A more practical role of animations in proofs is to reinforce conventional teaching methods and illustrate examples. Students with an existing understanding of the material have shown better response to animations than those using animations to learn new topics (Stasko et al, 1993).

## 2.4 Available Software

Many software packages are available for the creation of animations with many levels of complexity. Some have been written specifically for the animation of algorithms, and are typically available without cost for educational purposes. However, most are commercial packages, and some assume the user knows a great deal about the theory behind animations, targeting professional graphics designers. The more relevant packages target web developers who may not have a strong background in computer science. Some of these packages provide a more visual, 'what-you-see-is-what-you-get' approach. The commercial packages are typically more widely used than educational tools, which make it easier to find support and helpful users to answer questions. The cost of such packages can prove a serious roadblock to some educators, as can the lack of portability and necessity for client-side software that can view the finished animations correctly.

# 3. Methodology

## 3.1 Resources and Participants

Participants of this study consisted of 83 students from the undergraduate level CS2022 – Discrete Mathematics course at Worcester Polytechnic Institute, taught by Professor Karen Lemone. Participants completed a preliminary survey written by Catherine Jester to evaluate their learning styles between 4 categories: visual/verbal, visual/non-verbal, auditory, and kinesthetic.

Animations created for this study were implemented in HTML with JavaScript, partly with the use of the Dreamweaver program. These animations demonstrate induction proofs, a topic taught regularly in the Discrete course.

All animations were presented to students through the course website maintained by Professor Lemone. Surveys used to determine learning styles and evaluate student understanding were also presented through the website. Students were required to complete an evaluation survey before viewing the animations.

## 3.2 Procedure

Students were required to complete an online learning styles survey as part of a weekly homework assignment. Data from this survey was then processed with software written by the author to replace student names with a numerical identifier.

Mathematical Induction was introduced through daily class lectures and assigned textbook readings. Students were then required to view an online presentation about induction as part of a weekly homework assignment. Immediately following this presentation students were required to complete a survey qualitatively rating the usability and efficacy of the presentation. Data from this survey was automatically cross-correlated with the learning styles data to remove student names and assign a numerical identifier. Results were then compiled correlated against the results of the learning styles survey to determine if any particular learning style benefits more from the animations.

The path taken for creating the proof presentations in this paper is similar to that of creating algorithmic animations. The steps of the proof become steps of an algorithm that is transforming sample data. In the case of induction proofs this may require several iterations to produce the base case for the proof, and therefore limits the scope of sample values that can be used in the animation.

## 3.3 Rationale

Induction was chosen as a topic for the animations because of past difficulties undergraduate and graduate students have experienced when writing proofs. Homework from the participating class indicated few students were able to produce even the initial induction step for sample proofs, indicating they have problems understanding induction itself. Professor Lemone also teaches a number of graduate courses exclusively over the Internet, some of which cover induction as a principle tool for proofs. She has experienced greater problems when the solutions are not covered in a face-to-face lecture. One goal of these animations is to facilitate teaching induction over the web, something that has been problematic in the past because students have not understood the material.

### *3.3.1 Evaluation Criteria for Software*

Care was taken while producing the animations to create a product that could be edited in the future. Knowledge of JavaScript and HTML is required to edit animations produced outside Dreamweaver, placing potentially severe restrictions to editors of the animations outside the computer science field. However, because the animations were designed to be used in a college level computer science department, it is expected that more professors will understand these concepts and be able to perform the editing role without the significant overhead of learning JavaScript and HTML.

The use of animations in education relies on three roles. The creator designs and manufactures the animation, and must have a full understanding of the software used to generate and distribute the visualizations. While some animations may be created by students as part of coursework or research, for animations to become useful as a standard teaching tool the work must be done by teaching assistants or teachers themselves. This would favor a simpler tool for creation of animations that would require fewer overheads to learn. Tools requiring the knowledge of a particular programming language or detailed script become less attractive for the creator as the time involved developing a single animation escalate.

An important but often overlooked role in the animations process is the editor, assumed to be the teacher utilizing the animation. A professor may require changes to the material presented in the animation to correct mistakes, adapt the visualization over iterations of a course, or modify a particular animation to apply to another topic. Editing makes existing animations more flexible, and can alleviate the need for a creator of new animations. The creator of a particular animation may no longer be available, as is the case when the creators are students. Some animations are posted online, where professors can download and adapt them. Compiled animations can be very difficult, if not impossible, to edit, and scripted animations require some knowledge of the scripting language to modify. A format that can be easily modified without rewriting most of the animation becomes very desirable.

The third role is that of the consumer, or student. In this case the sole purpose is to communicate the desired material in a clear method that is easy to access. Here the student may benefit from a package with more complicated options and animation techniques, which may make the roles of the creator and editor more complicated. Packages that offer geographical translation, or moving an image from one location on the screen to another, may produce more effective animations that allow the student to easily follow the transition from one step to another.

While the educational value of the animations with respect to students is often the ultimate goal, it is important not to overlook the creating and editing roles. An extremely complicated animation technique may provide excellent results but does little good if teachers cannot reproduce the method because it is too complicated or time consuming.

HTML with embedded JavaScript was chosen for implementing the animation presentation, while all surveys were presented in HTML. Because HTML and JavaScript are viewable on nearly every modern Internet browser, this solution was well suited for the students viewing the material. A complete discussion of reviewed software is available in Appendix A.

# 4. Results

The learning styles survey was completed by 69 students, twelve of whom were categorized as multiple learning styles. 53 students displayed dominant visual/non-verbal style, 15 displayed dominant visual/verbal, 6 displayed dominant auditory style, and 10 had dominant kinesthetic style. Figure 4.1 displays each learning style and the percentage of students who displayed a dominant tendency for that style.

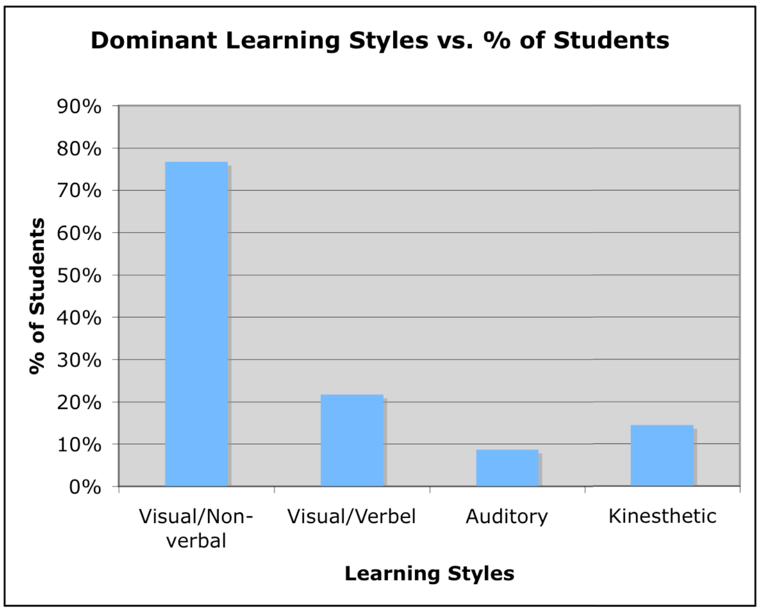


Figure 4.1 Dominant Learning Styles of Participants

The usability survey for the first trial was completed by 71 students, indicating at least 71 students viewed the first trial animations. On the first question of the survey, 69 students indicated images appeared in the bottom right corner of the presentation. Two did not see any images. See Figure 4.2.

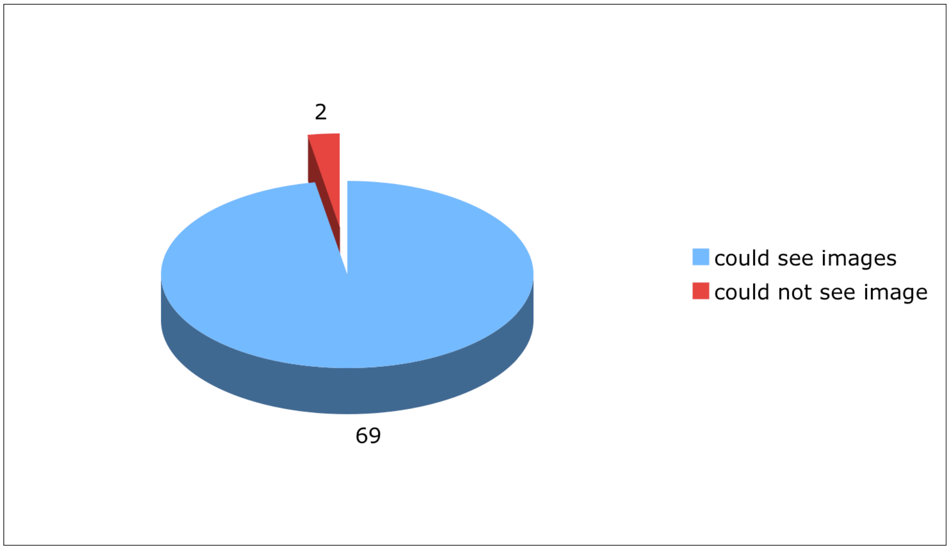


Figure 4.2 Capability of Students to View Images in Presentation

On the second question, 63 students indicated the images animated when clicked. 5 students did not click on the images, 1 did not see any images, and two had other problems. Of these two, one could not initially view the images because of browser incompatibility, and the other did not realize the images would animate if clicked.

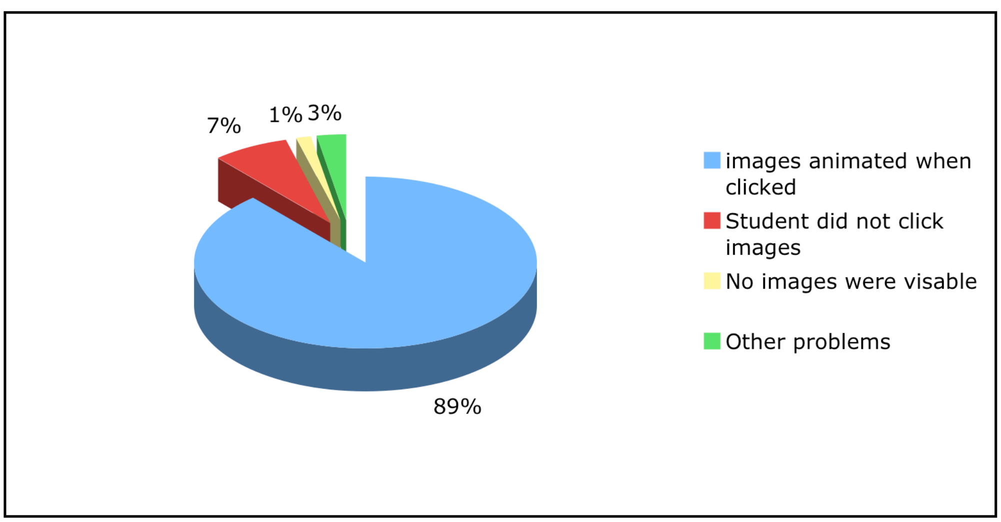


Figure 4.3 Functionality of Animated Images

On the third, fourth, and fifth questions all students responded with choice (a), indicating they could read all text clearly, saw three different topics appear, and understood the base case. See Figure 4.4.

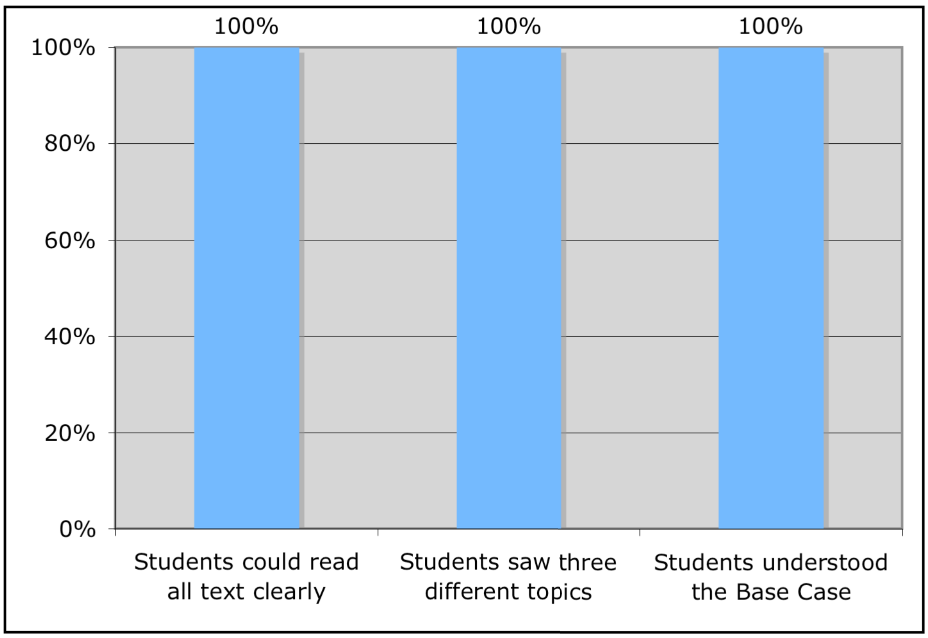


Figure 4.4 Usability Measures of Presentation

On the sixth question 68 students responded that they understood the induction hypothesis that was presented, while 3 indicated they did not understand it. See Figure 4.5.

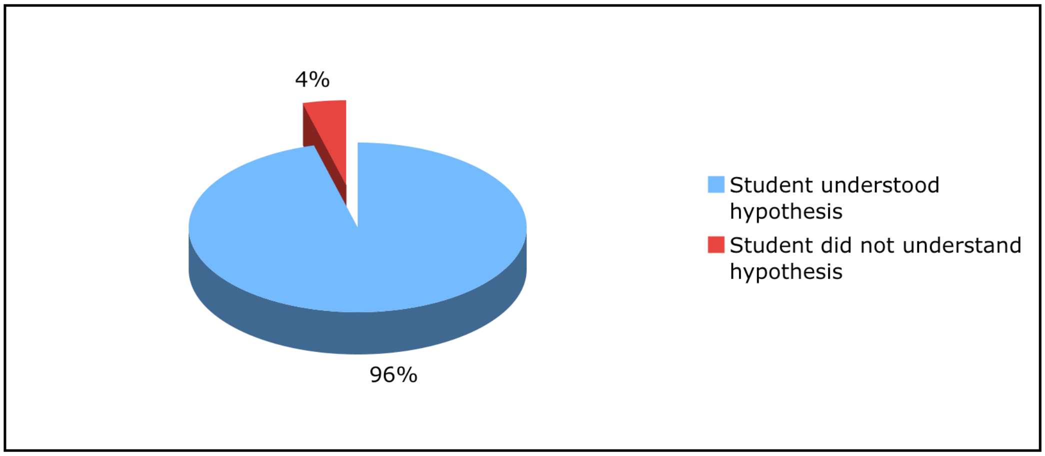


Figure 4.5 Student Comprehension of Induction Hypothesis

On the seventh question 42 students indicated that the presentation helped the student to understand induction. 3 students responded that it was no help at all, and 26 students indicated they completely understood induction prior to viewing the presentation and didn't need to view it. See Figure 4.6.

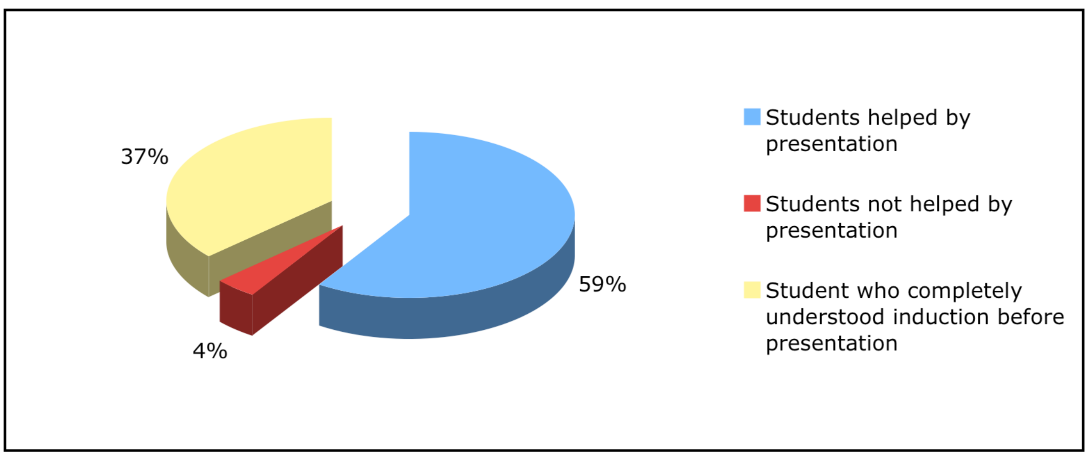


Figure 4.6 Assistance of Presentation for Facilitating Student Understanding of Induction

On the eighth question 66 students responded that they would not make any improvements to the material presented. Of the 5 who suggested changes, one suggested using Flash to improve the interface, one suggested using less frames, one claimed the layout was confusing on very high resolution monitors, and one suggested improvements for the lecturing done during class sessions. The fifth suggestion suggested breaking the induction hypothesis into two parts to clarify it. The first part would show that n => n+1, while the second would demonstrate how the base case (n = 1) implies n = 2, which implies n = 3, and so on.

On the ninth question 62 students responded with no suggestions to improve the presentation in general. 9 students made suggestions, which included 7 suggestions to improve the interface, including using Flash for the animations, fixing several bugs involving moving buttons, making certain parts of the interface attract more attention, changing the control buttons, and adding more automation. Of the remaining two suggestions one was an irrelevant comment, and one focused on improving the material by showing the induction hypothesis first and the base case last.

Of the 71 students who completed the first trial survey, 57 of them also took the learning styles survey. On question number 6, 3 students responded that they did not understand the induction hypothesis. All of these students took the learning styles survey, and one student showed auditory dominance while all three showed visual/non-verbal dominance. See Figure 4.7.

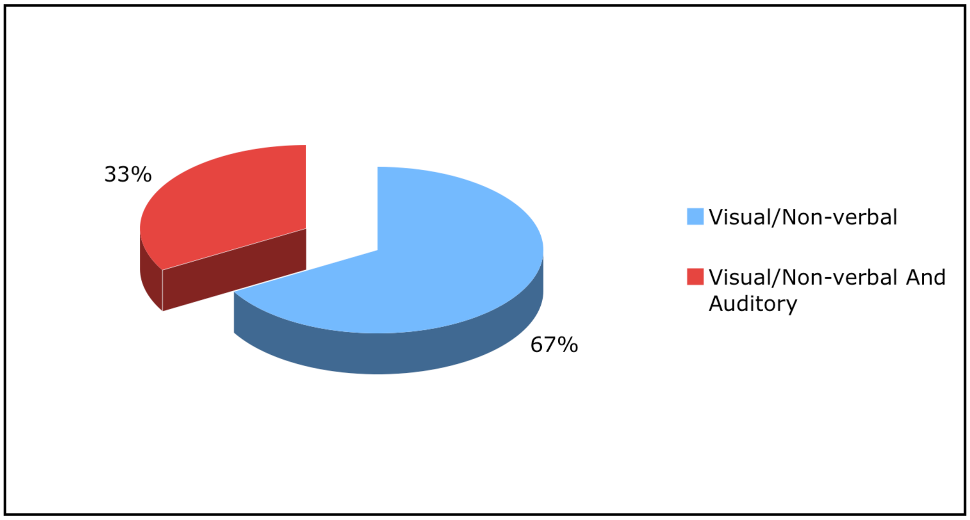


Figure 4.7 Learning Styles of Students who did not Understand Hypothesis

On question number 7, 42 students answered that they believe the presentation helped them understand induction. Of these students, 32 of them took the learning styles survey. 26 of these 32 displayed visual/non-verbal dominance, 10 displayed visual/verbal dominance, 3 displayed auditory dominance, and 6 displayed kinesthetic dominance. Students could be dominant in more than one style.

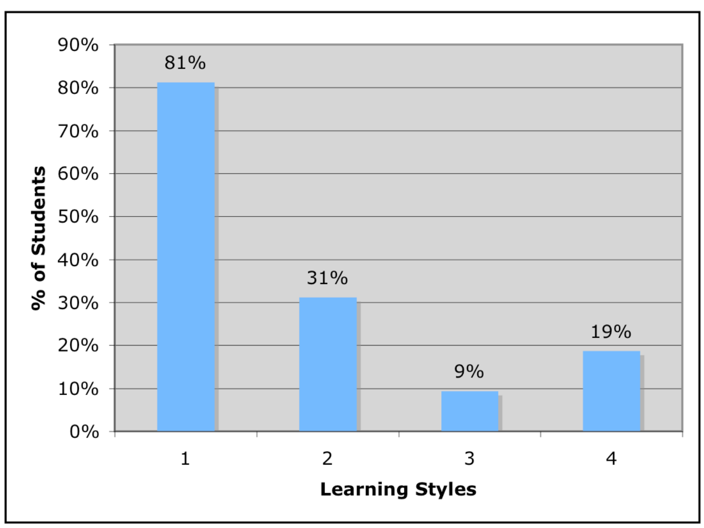

Figure 4.8 Learning Styles of Students Helped by Presentation

Three students responded on question 7 that the presentation did not help them. All three took the learning styles survey; there was one student dominant visual/non-verbal, one visual/verbal, and one kinesthetic.

Of the 26 students who responded they already completely understood induction, 22 took the learning styles survey. 17 were dominant visual/non-verbal, 2 were dominant visual/verbal, and 3 dominant auditory.

# 5. Conclusion

The results of the learning styles survey indicated that the overwhelming majority of students tested were dominant visual/non-verbal learners. Visual/verbal and kinesthetic styles make up much of the remainder, with dominant auditory the least favored. Lecturing, a style that favors strong auditory learners, is the predominant method of instruction used for this class. While it may be a practical means of teaching, very few students measured dominance in the auditory learning style it favors.

## 5.1 Students Helped by the Induction Presentation

The animations presented in this study were intended to appeal to both visual/verbal and visual/non-verbal by including both text and images that demonstrated the concepts presented in the text. It also included a degree of interaction that engaged kinesthetic learners. Of the students who believed the presentation helped them to understand induction, the sampling of learning styles was roughly equivalent to the overall sampling, with the exception of visual/verbal dominant learners. There were slightly more of this learning style, with 31% of the students helped by the induction principles measuring dominant visual/verbal compared to 22% of the overall group displaying this dominance. This indicates the presentation at best favored visual/verbal students in teaching the principles of induction, or at least increased their confidence in the material more than other learning styles.

## 5.2 Students Not Helped by the Induction Presentation

Of students who reported that the presentation was no help to them in terms of understanding induction, all were measured as being dominant visual/non-verbal learners. This strengthens the position that the visual/verbal style was favored in this presentation.

A number of students responded that they already completely understood induction and the presentation was no help to them. While some of these students most likely did already understand induction, it is possible some of them overconfidently assessed their understanding on the subject, as is common among college students. It is unlikely they would still rate themselves as having mastered induction on the survey if they learned anything new. Hence, if such overconfident students were to be correctly categorized, they could only be assessed as receiving no benefit from the presentation and thus be counted against the efficacy of this presentation.

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# Appendix A: Software Review

Several software packages and techniques were reviewed during the course of this project. Microsoft PowerPoint, Macromedia Dreamweaver, Macromedia Flash, simple HTML, and HTML with JavaScript were examined, along with a cursory look at larger, commercial animation packages.

All professional animation packages were rejected for several reasons. They all require significant overhead on the part of the creator to learn how to operate the software. This overhead is also passed to the editor, as no editing is possible without the original program. Such editing would also require the original source files, as the presentation would be distributed in a compiled or 'rendered' form which is impossible to edit. Some of these packages also required special plugins to view the product, although some are capable of producing common images viewable through a web browser. As such packages present obvious initial difficulties for creator, editor, and user, they were not reviewed in detail.

Microsoft PowerPoint is a tool commonly used by professors to provide visual links while lecturing. Animations produced using it could be integrated easily into presentations, and then be posted on a course website in the same format. Because it is fairly easy to learn and many teachers have existing knowledge from using it to create presentations, it cuts down on overhead for the creator and editor roles. The animation functions in the generally supported PP97 format are limited only to making new images appear on a slide, or 'entrances'. The new XP version of the program also supports exits as well as 'motion paths', or smooth translation of images within a slide. Such motion paths can improve viewer comprehension of an animation because the viewer does not have to figure out what changed between two static images (Stasko et al, 1993).

PowerPoint XP presents problems at the consumer end because animations which include motion paths and exits can only be viewed on newer windows machines with PowerPoint XP or the correct Microsoft Internet Explorer version containing certain ActiveX controls (support.microsoft.com, 2004).

Macromedia Dreamweaver is a tool for building web pages, focusing on interactive content. While a more complicated program than PowerPoint, Dreamweaver offers more options for interactively formatting text and images. Dreamweaver creates HTML pages that include JavaScript to animate objects within the pages. Unlike PowerPoint, which creates a single sequence of frames, HTML pages and JavaScript can create a presentation, which allows the viewer to make decisions that choose the material to display. Editing Dreamweaver content is possible outside the program, although difficult. The automatically generated JavaScript code is complex, although the HTML code is fairly easy to modify. The largest advantage to using Dreamweaver is the compatibility of its product. HTML with JavaScript can be viewed on any modern web browser that has JavaScript support enabled, including the popular Microsoft Internet Explorer, Netscape and Mozilla.

Macromedia Flash was also considered for its convenient packaging and manipulation of images, as well as the large degree of interaction possible in the final product. Along with the drawbacks of learning overhead and being a commercial product, Flash requires a browser plugin distributed by Macromedia to view the created presentations. Such a plugin is not standard on all browsers, and installing it may deter potential viewers. The plugin does make Flash more compatible than PowerPoint, as it is possible to obtain basic Flash function for environments other than Windows XP.

The final method considered was HTML with JavaScript, which is the form produced by Dreamweaver. In this presentation such content was handwritten, based loosely around the Dreamweaver animation concepts in JavaScript. Dreamweaver-produced JavaScript was very difficult to understand if read as source code, and even more difficult to edit correctly, so by handwriting such code it was possible to add comments, white space, and embedded directions which make the editing job easier. Similar to Dreamweaver, no plugins are needed to view the presentation as all modern mainstream browsers handle JavaScript. However, it is possible to edit the presentation in any text editor, provided the editor has some basic understanding of JavaScript or computer coding in general. It is also possible for other instructors to save the presentation as it appears in their browser, edit it to suit their needs, and redistribute it through their own web servers without the need for proprietary programs or original source files. There are two obvious downsides to this method. Content is limited to the scope of HTML and JavaScript, which makes complicated interactive imagery difficult, but not impossible, to produce. The creating role is also fairly time consuming, and requires knowledge of JavaScript and HTML.

# Appendix B: Learning styles survey

**(Text version of online form used to administer survey)**

Your name:

1. I would rather read material in a textbook than listen to a lecture.

Often Sometimes Seldom

2. I benefit from studying with a partner or a study group.

Often Sometimes Seldom

3. In my spare time, I like to do projects that involve using my hands (e.g. painting, constructing, using tools, etc.)..

Often Sometimes Seldom

4.I find graphs and diagrams useful in clarifying concepts.

Often Sometimes Seldom

5.I benefit more from lab classes than lecture classes.

Often Sometimes Seldom

6. I find it useful to read out loud when reading a textbook.

Often Sometimes Seldom

7. Reviewing information on flashcards helps me remember it..

Often Sometimes Seldom

8. I like solving mazes or jigsaw puzzles.

Often Sometimes Seldom

9. I can find the mistakes in my written work.

Often Sometimes Seldom

10.I find myself talking out loud when studying by myself.

Often Sometimes Seldom

11.As a child, I liked to engage in physical activities during my free time.

Often Sometimes Seldom

12. I would rather listen to a book on tape than read it

Often Sometimes Seldom

13. I like solving crossword or word search puzzles.

Often Sometimes Seldom

14. I tend to doodle during lecture by drawing on my notebook pages.

Often Sometimes Seldom

15. When trying to remember a phone number, I "let my fingers do the walking," i.e. my fingers seem to remember the number on their own.

Often Sometimes Seldom

16. As a child, I liked to read books during my free time.

Often Sometimes Seldom

17. I would rather listen to a lecture than read the material in a book.

Often Sometimes Seldom

18. I can use a map effectively to get myself to a new location.

Often Sometimes Seldom

19. As a child, I liked to listen to stories told to me, or stories on tape, record player, or radio.

Often Sometimes Seldom

20. When learning a new skill, I would rather watch someone demonstrate the skill than listen to someone tell me how to do it.

Often Sometimes Seldom

21. When trying to remember a phone number, I can "see" the number sequence in my head, or I "see" the way the numbers look on the phone.

Often Sometimes Seldom

22. When trying to remember how to spell a word, I spell the letters with my finger in the air or on a table top.

Often Sometimes Seldom

23. If I have to learn how to assemble something, I would rather look at a diagram than listen to someone tell me how to put it together.

Often Sometimes Seldom

24. When trying to remember how to spell a word, I write down the word using alternative spellings until I see the spelling sequence I think is correct.

Often Sometimes Seldom

25. When trying to remember a phone number, I "hear" the number sequence in my head in the way someone told me the number, or in the way I previously recited the number out loud.

Often Sometimes Seldom

26. I like "hands on" learning better than learning from lecture or textbook.

Often Sometimes Seldom

27. I would rather have written directions than oral directions.

Often Sometimes Seldom

28. When trying to remember how to spell a word, I say the letters or sounds out loud until I think I've got the spelling right.

Often Sometimes Seldom

29. I learn better by doing than observing.

Often Sometimes Seldom

30. As a child, I liked to play with puzzles in my free time.

Often Sometimes Seldom

31. When taking a test, I can "see" the answer in my head as it appeared in my notes or textbook when I studied.

Often Sometimes Seldom

32.I learn best when physical activity is involved.

Often Sometimes Seldom

This test is duplicated from http://www.metamath.com/multiple/multiple_choice_questions.cgi for educational purposes.

# Appendix C: Results of learning styles survey

Student 1 - Visual/Nonverbal
Student 2 - Visual/Nonverbal
Student 3 - Visual/Nonverbal
Student 4 - Visual/Nonverbal, Kinesthetic
Student 5 - Visual/Nonverbal
Student 6 - Kinesthetic
Student 7 - Kinesthetic
Student 8 - Visual/Nonverbal
Student 9 - Visual/Nonverbal
Student 10 - Visual/Nonverbal
Student 11 - Visual/Nonverbal, Visual/Verbal
Student 12 - Visual/Nonverbal
Student 13 - Visual/Nonverbal
Student 14 - Visual/Nonverbal, Kinesthetic
Student 15 - Kinesthetic
Student 16 - Visual/Verbal
Student 17 - Visual/Nonverbal
Student 18 - Visual/Verbal
Student 19 - Auditory
Student 20 - Visual/Nonverbal
Student 21 - Visual/Nonverbal
Student 22 - Visual/Nonverbal
Student 23 - Visual/Nonverbal
Student 24 - Visual/Nonverbal, Visual/Verbal
Student 25 - Visual/Nonverbal
Student 26 - Visual/Nonverbal
Student 27 - Auditory
Student 28 - Visual/Nonverbal
Student 29 - Auditory
Student 30 - Visual/Nonverbal, Visual/Verbal
Student 31 - Visual/Nonverbal
Student 32 - Visual/Nonverbal
Student 33 - Visual/Nonverbal
Student 34 - Visual/Nonverbal, Visual/Verbal
Student 35 - Visual/Nonverbal
Student 36 - Visual/Nonverbal
Student 37 - Visual/Nonverbal
Student 38 - Visual/Nonverbal
Student 39 - Visual/Nonverbal, Kinesthetic
Student 40 - Visual/Verbal
Student 41 - Visual/Nonverbal, Auditory
Student 42 - Visual/Nonverbal
Student 43 - Visual/Nonverbal, Auditory, Kinesthetic
Student 44 - Visual/Nonverbal
Student 45 - Visual/Nonverbal

Student 46 - Visual/Verbal
Student 47 - Visual/Nonverbal
Student 48 - Visual/Nonverbal
Student 49 - Kinesthetic
Student 50 - Visual/Nonverbal, Visual/Verbal
Student 51 - Visual/Verbal
Student 52 - Visual/Nonverbal
Student 53 - Visual/Nonverbal
Student 54 - Visual/Nonverbal
Student 55 - Visual/Verbal
Student 56 - Visual/Nonverbal, Visual/Verbal
Student 57 - Visual/Nonverbal
Student 58 - Visual/Nonverbal
Student 59 - Visual/Verbal
Student 60 - Kinesthetic
Student 61 - Visual/Nonverbal
Student 62 - Visual/Nonverbal
Student 63 - Visual/Nonverbal
Student 64 - Visual/Nonverbal, Visual/Verbal, Auditory, Kinesthetic
Student 65 - Visual/Nonverbal
Student 66 - Visual/Nonverbal
Student 67 - Visual/Nonverbal
Student 68 - Visual/Nonverbal
Student 69 - Visual/Verbal
Total Dominant Visual/Non-Verbal : 53
Total Dominant Visual/Verbal : 15
Total Dominant Auditory : 6
Total Dominant Kinesthetic : 10

# Appendix D: Usability Survey following Animation Presentation

**(Text version of online form used to administer survey)**

The following survey is used to help improve this site and collect data about it.

**You MUST COMPLETE it to get credit on the homework, but the answers you choose will have no effect on your grade (there is no right or wrong answer).**

There are 9 questions, it should only take a few minutes to complete.

Your name:

1) Did domino images appear in the bottom right corner of the presentation?
- Yes, several images appeared there throughout the presentation.
- I only saw one image appear there.
- No, I didn't see any such images.

2) Did these images animate when you clicked on them?
- Yes, they animated when I clicked on them.
- No, nothing happened when I clicked on the images.
- I didn't click on them.
- I didn't see any images.
- There was some other problem with the images:

3) Could you read all the text clearly?
- Yes, I didn't have a problem.
- No, I couldn't read the text because:

4) Did you see three different topics appear: the Base Case, the Induction Hypothesis, and an Example (n = 3)?
- Yes, I saw all of them.
- No, I missed some or all of them.

5) Did you understand the Base Case that was presented?
- Yes, I understood it.
- No, I didn't understand it.

6) Did you understand the Induction Hypothesis that was presented?
- Yes, I understood it.
- No, I didn't understand it.

7) Did this presentation help you to understand Induction?

- Yes, it helped me to understand induction.
- No, it was no help at all.
- I already completely understood induction and didn't need this presentation.

8) Are there any suggestions you would make to improve the material presented?
- No, it looked fine.
- Yes, I would change:

9) Can you suggest anything else to improve the presentation in general?
- No, it all seemed to work great.
- Yes, I would change:

# Appendix E: Results of Usability Survey

1) Did domino images appear in the bottom right corner of the presentation?

- 69 (97.2%) Yes, several images appeared there throughout the presentation.
- 0 (0.0%) I only saw one image appear there.
- 2 (2.8%) No, I didn't see any such images.

2) Did these images animate when you clicked on them?
- 63 (88.7%) Yes, they animated when I clicked on them.
- 0 (0.0%) No, nothing happened when I clicked on the images.
- 5 (7.0%) I didn't click on them.
- 1 (1.4%) I didn't see any images.
- 2 (2.8%) There was some other problem with the images...

    - They all animated when they were supposed to, except I thought that all of them were animated. That threw me off for a little bit (the first 2 slides of the 3 domino example).

    - It didn't work in Firefox for me, but did work in IE

3) Could you read all the text clearly?
- 71 (100.0%) Yes, I didn't have a problem.
- 0 (0.0%) No, I couldn't read the text because...

4) Did you see three different topics appear: the Base Case, the Induction Hypothesis, and an Example (n = 3)?
- 71 (100.0%) Yes, I saw all of them.
- 0 (0.0%) No, I missed some or all of them.

5) Did you understand the Base Case that was presented?
- 71 (100.0%) Yes, I understood it.
- 0 (0.0%) No, I didn't understand it.

6) Did you understand the Induction Hypothesis that was presented?
- 68 (95.8%) Yes, I understood it.
- 3 (4.2%) No, I didn't understand it.

7) Did this presentation help you to understand Induction?
- 42 (59.2%) Yes, it helped me to understand induction.
- 3 (4.2%) No, it was no help at all.
- 26 (36.6%) I already completely understood induction and didn't need this presentation.

8) Are there any suggestions you would make to improve the material presented?
- 66 (93.0%) No, it looked fine.
- 5 (7.0%) Yes, I would change...

    - I'd suggest breaking the induction hypothesis into two parts: the first is proving that if dominoe n falls, then dominoe n+1 falls also. After that go back and show how with the base case implies n = 2, then n = 3, etc. It all seemed crammed together and therefore not very clear.

- Not here, but certainly in class. It is totally approached towards CS majors, and those of us who aren't dont understand, I know several people who think the same as I do.

- Probably less frames.

- The layout is confusing. The frame on the left is very large on high monitor resolutions, like 1600x1200. I'm a graphic designer, so naturally I noticed the interface problems. Other than that its a neat tool.

- The layout was alright, but it it needs to have a smoother interface to better understand what is going on. Flash might help there.

9) Can you suggest anything else to improve the presentation in general?

- 62 (87.3%) No, it all seemed to work great.
- 9 (12.7%) Yes, I would change...

  - Set up the dominos first, we all know that if they're setup correctly (if P(n) -> P(n+1)) then they will all fall. Show the base case last. It makes more sense this way, I think.

  - Show the animation right after the base case and the hypothesis, ppl usually forget to click to animate

  - When you clicked on buttons, it shifted the next button down on the page which seemed unprofessional -- I guess a little clean up of the interface is all I would change.

  - I would recommend that you alter the page so that users do not have to click "start" to begin using the demonstration, or else highlight the start button in some way. when i first accessed the page, i totally failed to notice this button and thought perhaps that it was not display right. after reloading the page a few times, i realized that there was a start button - but it is really not as visible as it should be for ease of use.

  - Use Flash for the animations? Just an idea....

  - There were too many steps when the user had to click on the next button. It should put the previous step into its spot on the left and immediately show the next step without requiring the user to press the next button again. Also, I had to reload the page twice because the next button didn't "ungrey."

  - There were too many steps when the user had to click on the next button. It should put the previous step into its spot on the left and immediately show the next step without requiring the user to press the next button again. Also, I had to reload the page twice because the next button didn't "ungrey." The image for the final case (n=3) should not have to move down. The text boxes should just appear, and the image should be stationary near the bottom.

  - Just make the interface a bit more logical. Play controls should simulate a

VCR, since that's what people are accustomed to. Tooltips should be big and noticable, such as "Click the image to see an animation", it should have large text and maybe an arrow to get the user's attention.

- dominoes are not blue