THE DESIGN AND DEVELOPMENT OF A USER-CONTROLLED VISUAL AID FOR IMPROVING STUDENTS' UNDERSTANDING IN INTRODUCTORY STATISTICS

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ABSTRACT

The use of visual aids is expected to have a positive effect on students' learning. However, not all visual aids work equally well. A recent meta-analytic research which examined 42 studies has found that the use of animated visuals does not facilitate learning (Anglin, Vaez & Cunnincham, 2004). The failure of visual aids can be attributed to factors such as violating the congruence and apprehension principle, lacking appropriate control functions, and mediation by individual characteristics. Across the board, researchers note the lack of appropriate user-control functions as the key factor.

Interactivity, or the user-control mechanisms of animation, is pointed out as a factor for users to better apprehend the knowledge which the visual aid aims to deliver. The functions of stopping, starting and replaying allow students to re-inspect the animation. Consequently, students can focus on specific parts and actions of the visual aid. In addition, animations that allow users to control close-ups, zooming, and speed are more likely to facilitate perception and comprehension (Tversky et al, 2002). This study focuses on creating an animated visual aid with appropriate self-controlled functions to better help students' learning of introductory statistics. We consider different levels of interaction for mediating students' individual differences.

Keywords: Animated Visual Aid, Statistics Education, Instructional Design, User-control Function.

INTRODUCTION

Proposal

The teaching and learning of statistics has pervaded all levels of education, including post-secondary, college-level and graduate-level curriculums (Garfield & Ahlgren, 1988). For college- and graduate-level students, statistics has become a requisite course for a wide range of fields. This level of education requires enhanced cultivation of quantitative and logical thinking, and additionally provides skills necessary for future employment choices. College statistics courses are expected to offer students tools for trimming the mass of information, ordering the messiness, separating sense from nonsense, and selecting the relevant few from the irrelevant many in real world data (Ben-Zvi, 2000). However, students face many challenges in statistics courses. Researchers have found that students are not capable of obtaining an adequate understanding of basic statistics concepts. Also, students are not able to solve applied problems (Garfield, 1995). Studies show that students often respond to statistical problems by falling into a "number crunching" mode. That is, students plug in quantities into a computational formula or procedure without forming an internal interpretation of the problem (Garfield & Ahlgren, 1988).

The development of computer technology and the Internet provides solutions for college instructors to improve students' understanding of statistics. The visual aid, one powerful type of technological tool, has a high potential to overcome students' learning obstacles in statistics and decrease the learning curve. The term visual aid refers to a visual representation or a visual display that facilitates students' learning. Visual representations and visual displays are used interchangeably in the literature to characterize displays that represent objects, concepts, and their relations by using symbols and their spatial arrangement (Vekiri, 2002). Visual aids are frequently integrated into the classroom setting to support learning and to make the learning process more effective. The purpose of graphical displays is to provide the viewer a visual means of processing information (Segenchuk, 1997).

Since 1980, the visual aid has been viewed as an innovative strategy in education, especially for math or science related subjects. Different types of visual aids have been developed to enhance students' concepts formation. In computer science, for example, the impetus for visual aids comes from the abstractness of the concepts in the field. To make these concepts more concrete, graphical representations are suggested to help one to better understand how they work (Naps *et al.*, 2003). Also, in physics and chemistry classes, it is very common for teachers to integrate visualizations to show the molecular structure. To give students a clear understanding of molecular modeling, instructors can show a molecular simulation or engage students in creating a molecular simulation in the class (Allen, 2007). In a biology class, the instructor might use a simulated frog dissection as a preparation for an actual dissection or as a substitute for the dissection (Kulik, 2002). Medical science is also a field which relies on visual aids; simulation is used to train medical practitioners to diagnose patients (Savoldelli *et al.*, 2005). The above examples show the possibilities of integrating visual aids into educational use.

One popular way to organize visual displays is to categorize them into static or animated visuals, based on whether their graphical components can change with time or not. Static visuals are those in which the graphical elements being displayed can not change with time (Vekiri, 2002). Researchers began to explore the educational value of static visuals in the 1930's. Many functional frameworks have been presented for categorizing different type of static visuals. An example of a static visual is University of Washington's *Digital Anatomist Project*, which includes digital atlases to teach students human organs (Structural Informatics Group, 2007). According to Segenchuk (1997), the static visuals are capable of drawing an analogy to another domain of knowledge, serving as an intermediate representation to bridge the learners' prior knowledge and new knowledge, and making salient the important relationships within a concept.

Animated visuals are those in which the graphical elements being displayed can change with time (Vekiri, 2002). The study of animated visual aids began in the 1920's when the instructional film became popular. But with the progress of technology development such as JAVA and Flash, the animated visual aids now have been expanded from films to computer-based or internet-based software programs. This type of visual aid is increasing in educational materials across a range of subject disciplines and levels of study. Animations and simulations are examples of animated visuals. Animated visuals bring three attributes to an instructional setting: visualization, motion, and trajectory (trajectory refers to the direction of the path of travel of an animated object) (Rieber, 1990). Since animated visual aids create a more dynamic and interactive environment for learners than static visual aids, they are viewed as more powerful in helping students to construct mental schema.

Researchers or commercial units in the statistics education field have designed large amounts of online visual aids. In the 80's, tools with text-based interfaces such as Minitab and Graphing Calculator were popularly used to carry out the visualization and simulation strategy in the statistics classroom. Teachers used them to simulate distribution (Dambolena, 1986; Dambolena, 1986), Bayesian method (Albert, 1993) and the central limit theorem (Gordon, 1987). In the 1990's, educational visual aids with graphic-based interfaces were developed. Among these tools, ELASTIC (Environment for learning Abstract Statistical Thinking) was the most popular visual aid in statistics education (Rosebery & Rubin, 1989, 1990). In the 2000's, animated visual aid with internet-based Interface emerged. JAVA applets and flash applications continue to be the most popular tools among Internet-based tools. JAVA applets are computer applications designed for the internet. Applets are platform-independent, meaning that they can run on any operation system that has a JAVA Virtual Machine to translate applet byte codes to appropriate platform-dependent instructions. The advantages of JAVA applets include its better performance in speed, interoperability, user interaction, portability, network computing and development and maintenance (Kamthan, 1999). Some noted JAVA applets for statistics education are: Rice Virtual Labs in statistics, Elementary Statiscs JAVA applets, Statlets, StatCrunch, Statiscope, PsychStat, BusinessStat, Probability by Surprise, Web Interface for Statistics Education, CUWU Stats, PSOL, StatLab, Virtual Labs in Probability & Statistics, JavaStat, Vestac, JSci and CyberStats (Dinov et al., 2006). Flash is the most recent program for visual aid display in statistics education. One example is ConStatS, developed by Tufts University. ConStatS consists of 12 modules grounded into five distinct parts: representing data, probability, sampling, inference, and experiments. ConstatS uses Flash to develop the "point and click" graphic interface. Pull down menus are used to access datasets, exercises, experiments, and different topics.

The use of visual aids is expected to have a positive effect on students' learning. However, not all visual aids work equally well. In real world practice, instructors are often unsuccessful in using them. A recent meta-analytic research which examined 42 studies has found that the use of animated visuals does not facilitate learning (Anglin, Vaez & Cunnincham, 2004). The failure of visual aids can be attributed to factors such as violating the congruence and apprehension principle, lacking appropriate control functions, and mediation by individual characteristics. Across the board, researchers note the lack of appropriate user-control functions as the key factor.

Interactivity, or the user-control mechanisms of animation, is pointed out as a factor for users to better apprehend the knowledge which the visual aid aims to deliver. The functions of stopping, starting and replaying allow students to re-inspect the animation. Consequently, students can focus on specific parts and actions of the visual aid. In addition, animations that allow users to control close-ups, zooming, and speed are more likely to facilitate perception and comprehension (Tversky *et al.*, 2002).

Due to technological limitations, early researches on animated visual aids focused on uncontrollable animations. It is in the past five years that researchers begin to focus on the use of user-control animation in learning. However, the current findings are not yet inclusive. Some argued that the user-control functions are significantly helpful to learners (Mayer, 2001) but some do not. (Boucheix & Schneider, 2008) presented significant experimental evidence showing that providing user-control can not guarantee a positive learning result. This is because the user may not be able to respond to the user-control functions due to his prior knowledge or information management skills. In other words, the design of the user-control function needs to match users' ability or skills, or the use of animation may not succeed at all, more research needs to be done.

This study focuses on creating an animated visual aid with appropriate self-controlled functions to better help students' learning. The authors consider different levels of interaction for mediating students' individual differences.

The research questions are as follows:

- How do we establish user-controlled functions in the animated visual aid?
- How does the use of animated visual aids improve students' academic performance and confidence in statistics?

Hopefully this study will provide an example of how to design a user-controlled animated visual aid, as well as broaden the understanding of how the animated visual aid impact on learning. Also, this research could serve as a reference for future statistics curriculum designers, textbook publishers or instructors to design or implement the curriculum or courses using visual aids.

System Design and Development

Content Selection

The unit which the authors selected to develop an animated visual aid for is *the principles of hypothesis testing*. The purpose of our design is to help students learn to set up a hypothesis test and to interpret the results. Most students are able to follow the basic procedures for testing hypotheses. However, even after discussing what Type I and II errors signify, students inevitably ask, "but where do you get alpha(α)?" (Smith, 2003) Students' difficulties in grasping the underlying principles of hypothesis testing strongly reduce their ability to interpret the testing results. Though these are important concepts in fundamental statistics, few studies focus on cultivating of students' understanding of hypotheses testing. A visual aid was designed and developed to uncover students' difficulties and test whether the aid could improve their understanding. Through the learning of this unit, students are expected to distinguish the null hypothesis from the alternative hypothesis, and apply the concept of alpha, beta and p-value to make decisions in the significance testing. The specific objectives which students need to achieve include:

- The student is able to set up the null hypothesis as well as the alternative hypothesis using real-world problems.
- The student is able to understand the errors (type I and type II error) which could be made in the testing process.
- The student is able to calculate α, β, and p-value in real-world problems with different population shapes.
- The student is able to make a decision to the real-world problem based on the number of α, β, and p-value.

In the traditional classroom, the instructor teaches above concepts by using the textbook and blackboard. The following is one sample page of this unit from a textbook (Figure 1)

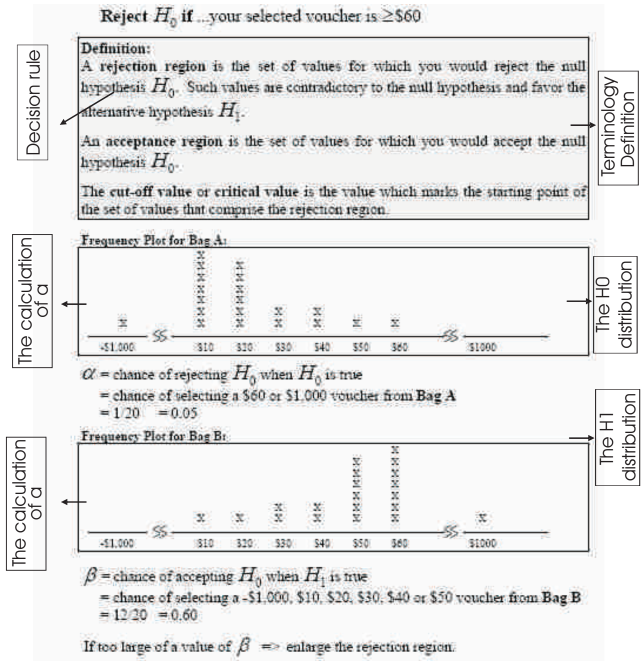

Figure 1. The exemplary page of traditional textbook for statistical language of hypothesis testing

With the use of the textbook, there is no way for students to interact with the numbers. All students can do is to passively read the definition and examples on the textbook. As a result, the effectiveness of it is very limited. This is why an animated visual aid is necessary here. The author's design of the animated visual aid is based on this introductory statistics textbook (Vaughn, 200X). The animated visual aid is expected to deliver the same contents as the textbook will, and the following section will elaborate it.

System interface design

The visual aid program is created by using Adobe Flash CS3 Professional and Action Script 2.0. It is designed as a 480px * 560px window. The small screen size of the visual aid makes it possible for the instructor and students to put it on any mobile device. But in this particular study, the laptop is the main device used(Figure 2).

The user-controlled mechanism is built inside the visual aid program. That is, users are allowed to have different levels of interactions based on their needs and preferences. Two different modes are created for users to interact with: the viewing mode and the practicing mode. The users are free to switch between two modes for learning.

The viewing mode allows students to watch the animated procedure of calculating α, β, and p-value. Students are allowed to select a H0 distribution, draw a random voucher from the bag, and set up a decision rule on the left-side area of the window. After the student click on the "viewing calculating" button, the processes of calculating α, β, and p-value will be shown on the right-

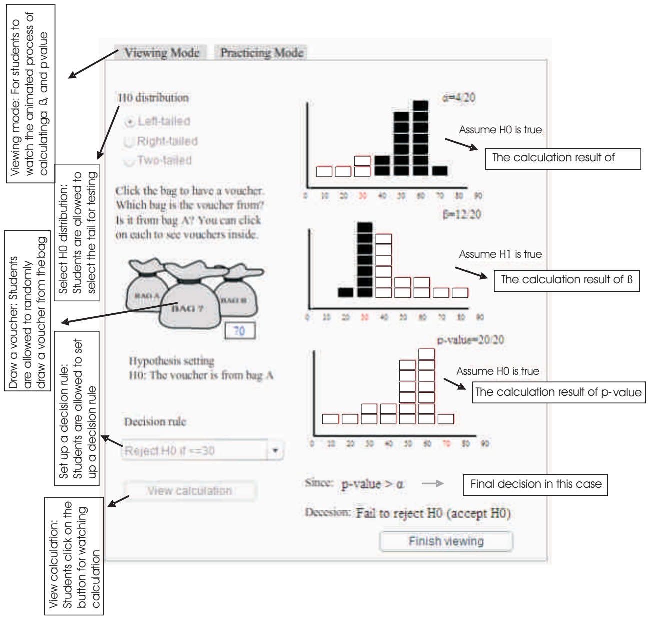

Figure 2. System Interface for the viewing mode

side of the window with graphs and boxes. Students are allowed to stop, start and replay any animation for re-inspection. The Figure 2 shows the viewing mode interface.

Figure 2 shows the calculation procedure of a one-sided testing. The left-side area on the window allows students to have different inputs. In this case, the H0 distribution is selected as a "left-tailed" distribution; the voucher drawn is set up as "70", and the decision rule is set up as "Reject H0 if value <= 30". The right-side area of the window shows the animation of calculation for α, β, and p-value. Three figures are used to illustrate the calculation. The top one shows the calculating procedure for α. The black boxes represent the voucher values in the H0 bag, and the white boxes represent those vouchers which fall into the rejection region. In this case, while calculating α, there are 20 boxes (vouchers) in the bag, and only 4 fall in the rejection region. As a result, α equals to four out of twenty (4/20). Similar calculation processes are animated on the middle and bottom figure for β and p-value. After the calculations are finished, the testing conclusion will be shown as texts on the bottom of the window. In this case, the program tells the students "since p-value>α, we fail to reject H0."

Only providing students the opportunities to re-inspect the animated procedure is not enough. In the visual aid program, the authors create another mode for students to have more advance interactions. That is, the practicing mode. Similar to the viewing mode, the practicing mode also allows students to select the H0 distribution, to draw a voucher from the bag, and to set up a decision rule. However, this time, students need to calculate the α, β, and p-value by themselves. There are totally 7 questions for students to solve in each round, and they need to use the graphs provided to do the calculation. The program will no longer show them any animation here. Students are asked to select the correct distribution by using the drop-down menu for each question and click on the black boxes on the graphs for doing calculating. After finishing calculating, students have to decide if the H0 hypothesis is rejected or accepted by selecting one item on the drop-down menu. When all questions are done, students can click on the "check my answer" button to check if they get all answers right. The program will show students if they get everything correct. The students can keep on trying until they get all answers right.

Figure 3 gives an example of how the student practices questions in the practicing mode. Similar with the viewing mode, the left-sided area on the window allows the students to have different inputs. In this case, the "left-tailed" distribution is selected as the H0 distribution, the

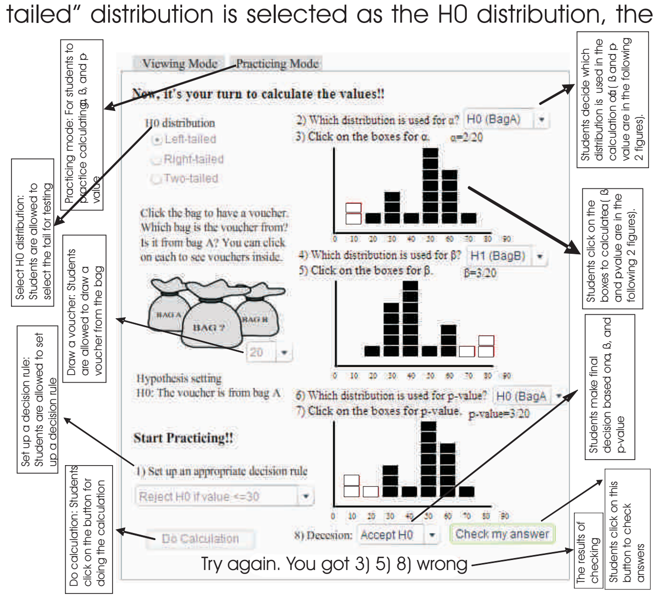

Figure 3. System Interface for the practicing mode

voucher value is set up as "20," and the decision rule is set up as "reject H0 if value <=30." After the student clicks on the "do calculation" button, 7 questions will be shown on the right-side of the window. The first two questions ask students to select a distribution for α and click on the black boxes to mark those which fall in the rejection region. In this case, the student selects the "H0 distribution" for α, and he clicks on the left two boxes to show the rejection region. As a result, the student's answer of α is two out of twenty (2/20). The calculation practice of β and p-value are similar with that of α. For the value of β, in this case, "H1 distribution" is selected and the right three boxes are marked white. The student's answer to β is three out of twenty (3/20). For the p-value, in this case, "H0 distribution" is selected and the left three boxes are marked white. The student's answer to β is three out of twenty (3/20). After comparing α and p-value, the student chooses to accept H0. However, while the student checks the answers, the program tells the student he gets three questions wrong: #3, #5, and #8. That is, the student has wrong answers to α, β, and the final decision. The student is allowed to redo this practice until he gets everything right. Or he may go back to the viewing mode to re-inspect the animation of calculation process.

There is no restriction for students to switch between the two different modes. Consequently, students could play in the viewing mode, go ahead to the practice mode, and then go back to the viewing mode again.

System Evaluation

Participants

The animated visual aid was put into an undergraduate introductory course for examining its effectiveness. 18 students are voluntarily joined in this study. These students came from different college and department with different majors, however, they are all novice learners of statistics and this course is their first course during their college life.

Pre- and post-tests

The pre- and post-tests are two paralleled tests in which questions are with the same content and difficulty. There are 12 multiple-choice questions on each test. For examining students' academic improvement in detail, they decompose the knowledge covered in this unit into 3 levels: the remembering-/understanding-level knowledge (3 questions), the applying-level knowledge (7 questions), and the analyzing-level knowledge (2 questions). For each question, there is a following question asking about student's confidence level, which ranges from 1 (very unconfident) to 4 (very confident). The reliability for the pre-test and post-test is .73 and .60.

Procedure

At the beginning of this study, all participants were given a 3-session lecture with the use of the textbook for learning statistical language and hypothesis testing. After finishing the lecture, students were asked to have a pre-test to evaluate their current knowledge of this particular unit. Then participants were asked to play with the animated visual aids. There was no time limitation for playing with the animated visual aids. Participants were free to stay in any mode of the animated visual aid and they are allowed to switch between the two modes. Most participants finished the visual aid manipulation in two hours. The post-test was assigned to these participants while participants finished up playing with the animated visual aid.

Findings

The scores on the pre- and post-test provided an assessment of the participant's general understanding about statistical language and hypothesis testing. The tests for the pre- and post-test scores are shown in Table 1 and Table 2.

	Pre-test		Post-test		Paired T-test	
	Mean	Sd.	Mean	Sd.	't'	Sig. (2-tailed)
Remembering-/understanding level knowledge	2.72	.57	2.67	.49	.0369	.717
Applying-level knowledge	4.06	2.21	5.17	1.50	-2.938	0.009 **
Analyzing-level knowledge	1.72	.46	1.89	.32	-1.144	.269

*Maximum possible score on remembering-/understand-leveling knowledge is 3
*Maximum possible score on applying-level knowledge is 7
*Maximum possible score on analyzing-level knowledge is 2

Table 1. Tests on students' academic performance

	Pre-test		Post-test		Paired T-test	
	Mean	Sd.	Mean	Sd.	`t`	Sig. (2-tailed)
Remembering-/understanding level knowledge	3.75	.28	3.89	.26	-.167	.110
Applying-level knowledge	2.80	.82	3.26	.55	-2.57	0.020**
Analyzing-level knowledge	3.09	1.00	3.72	.39	-3.00	.008**

*Maximum possible score on students' confidence is 4

Table 2. Tests on students' academic confidence

It can be seen from Table 1 and Table 2 that students' academic performance and confidence in the apply-level knowledge is significantly improved after the using the animated visual aid (t=-2.938, p=.009; t=-2.57, p=.020). The findings indicate that the animated visual aid contributes to students' learning of statistical language and hypothesis testing.

Discussion

The animated visual aid has a long history used in education including the statistics field. However, from the literature review, it is found that the helpfulness of the animated visual aid is over-expected. Many studies claimed that the animated visual aid does not contribute to learning. One of the important factors of the failure of animated visual aid is its lack of appropriate user-control functions. That is, animated visual aids can not work out if it does not allow users to stop, start and replay an animation for re-inspection.

The purpose of this study is to develop an animated visual aid which the users can have fully control. Therefore the researchers can further explore if the user-controlled visual aid helps learning and how it helps learning. They selected the principles of hypothesis testing as the unit for developing the animated visual aid, and the learning targets and content are all clearly defined before they develop it. Our animated visual aid is finally divided into two modes, the viewing mode and the practicing mode, which provide different level of interactions but the users can fully control any of the two modes. Also, users can freely switch between the two modes for figuring out concepts.

A small-scale system evaluation was conducted to see the performance of this animated visual aid. The system evaluation is designed as a pre- and post-test experiment with 18 voluntary undergraduate students. The results show that students' applying-level knowledge is significantly improved after the use of the animated visual aid. The applying-level knowledge here refers to make use of information in a context different from the one which it was learning. In other words, the applying-level knowledge means the ability to use strategy, concepts, principles and theories in new situations. It relates to learners' ability to compute, demonstrate and manipulate. In the principles of hypothesis testing unit, the applying-level knowledge means the students are able to set up the null/alternative hypothesis, calculate alpha, beta, and p-value with different population shape, and make a decision to the real-world problem.

The study shows that the use of user-controlled visual aid can significantly improve students' applying ability. Here they attach some applying-level questions which we use to evaluate students' knowledge. The following question is test question #13 for testing students' ability of calculating p-value.

QUESTION 13. There are two identical looking wallets - A and B and here are descriptions of the contents:

Wallet A: One $1 bills, Five $5 bills, Ten $10 bills

Wallet B: Eight $1 bills, Seven $5 bills, One $10 bills

A wallet is picked at random and exactly one bill is drawn at random from that wallet and shown to you. Based on the observation, you must decide which wallet the bill was drawn from.

Consider the following hypothesis.

H0: The bill is drawn from wallet A

H1: The bill is drawn from wallet B

Consider the decision rule: Reject H0 if the bill drawn is <=5, otherwise accept H0..

For the given decision rule, if the bill picked up is $1, compute the p-value

Before playing with the animated visual aid, only 7 students got this question correct. After playing with the animated visual aid, 12 students got this question correct. The following another question testing students' ability of calculating beta, the type II error.

QUESTION 15. A box contains many coins and all of them look identical. However only some coins are fair - when you toss a fair coin, the probability of getting heads is 1/2. The other coins are biased and assume that when a biased coin is tossed, the probability of getting heads is 2/3. They are given one coin from the box and asked to determine if it is a fair coin, by tossing the coin exactly once and basing our decision on the outcome.

Consider the null hypothesis, H0: The tossed coin is a fair coin.

Consider the decision rule: Reject H0 if we get heads.

Calculate β, the chance of making Type II error.

Before playing with the animated visual aid, only 5 students got this question correct. After playing with the animated visual aid, 9 students got this question correct. Students' scores significantly arise in almost every item of the applying-level questions.

Students' improvement not only reveals in their academic grades. Their confidence for solving applying-level question is also significantly enhanced. For applying-level knowledge, the students' average confidence level arises over 3 after playing with the visual aid. In this study of 4-point confidence scale, 3 is the starting point where students feel confident to their answers. In other words, the use of animated visual aid leads students from the unconfident status to the confident stats while solving the application questions. The enhancing of students' confidence in solving statistics questions helps cultivating their positive attitude and motivation in learning statistics. Consequently, it is valuable to instructors to integrate user-controlled visual aid in statistics course.

Interestingly, students' improvement is only shown in the applying-level knowledge. It seems students' remembering, understanding and analyzing level knowledge is not significantly improved. This might because this particular animated visual aid is directly designed for solving applied questions. In the visual aid environment, students are free to watch and practice the calculation of alpha, beta, and p-value with different kind of inputs. However, the remembering and understanding level knowledge is not directly delivered from the visual aid. So is the analyzing-level knowledge. For improving different level of knowledge other than the applying-level one, more instructions or associated worksheet might be designed and provided. How to optimize the use of animated visual aid for covering all level of knowledge will be the future goal of this study.

Conclusion

This study aims to develop a user-controlled visual aid to facilitate students learning statistics and examine how it helps students' knowledge and confidence improvement. The findings show that our particular animated visual aid could significantly improve student's academic performance and confidence in applying-level knowledge. For future research, we will continue revise the interactive functionality of the animated visual aid, create more associated worksheet or booklet for covering more level of knowledge, and increase our sample size to have more stable evidences of the strength and limitation of the animated visual aid.

References

[1]. **Albert, J. H. (1993).** Teaching Bayesian Statistics Using Sampling Methods and MINITAB. *The American Statistician*, *47*(3), 182-191.

[2]. **Allen, M.P. (2007).** Educational aspects of molecular simulation. *Molecular Physics, 105*(2), 157-166.

[3]. **Anglin, G. J., Vaez, H., & Cunningham, K. L. (2004).** Visual representations and learning: The role of static and animated graphics. In D. H. Jonassen (Ed.),*Handbook of research for educational communications and technology* (2nd ed., pp. 865916): Mahwah, NJ, Lawrence Erlbaum Associates, Publishers.

[4]. **Ben-Zvi, D. (2000).** Toward understanding the role of technological tools in statistical learning. *Mathematical thinking and learning, 2* (1&2), 127-155.

[5]. **Boucheix, J. & Schneider, E. (2008).** *Static and animated presentations in learning dynamic mechanical systems.* Retrieved June 10, 2008 from:

http://www.sciencedirect.com/science/article/B6VFW-4S8TW2S-2/2/40057b78cb2557f941e425b66efe7c95

[6]. **Dambolena, I.G. (1986).** The t distribution and computer simulation. *Mathematics and Computer Education, 20*(1), 10-13.

[7]. **Dambolena, I.G. (1986).** Using Simulation in Statistics Courses. *Collegiate Microcomputer, 4*(4), 339-344.

[8]. **Dinov, I. D., Sanchez, J., & Christou, N. (2008).** Pedagogical Utilization and Assessment of the Statistic Online Computational Resource in Introductory Probability and Statistics Courses. *Journal of Computers & Education*, *50*, 284300.

[9]. **Garfield, J. (1995).** How students learn statistics. *International Statistics Review, 63*(1), 25-34.

[10]. **Garfield, J. & Ahlgren, A. (1988).** Difficulties in learning basic concepts in probability and statistics: implications for research. *Journal for Research in Mathematics Education*, 19(1). 44-63.

[11]. **Gordon, F. (1987).** Computer Graphics Simulation of the Central Limit Theorem. *Mathematics and Computer Education, 21*(1), 48-55.

[12]. **Kamthan,, P. (1999).** *JAVA applets in education.* Retrieved June 10, 2008 from http://www.tech.irt. Org /articles/js151

[13]. **Kulik, J. A. (2002).** *School Mathematics and Science Programs Benefit from Instructional Technology.* National Science Foundation, Arlington, VA. Div. of Science Resources Statistics. Retrieved June 10, 2008 from http://www.nsf.gov/sbe/srs/infbrief/nsf03301/start.htm

[14]. **Mayer, R.E. (2001).** *Multimedia learning*. Cambridge University Press: Cambridge, MA.

[15]. **Nap, T., & etc. (2003).** Exploring the role of visualization and engagement in Computer Science Education. *Inroads-The SIGCSE Bulletin*, *35*(2), 131-152.

[16]. **Rieber, L. P. (1990).** Animation in computer-based instruction. *Educational Technology Research and Development, 38*(1), 77-86.

[17]. **Rosebery, A.S. & Rubin, A. (1990).** Teaching Statistical Reasoning with Computers. *Teaching Statistics, 12*(2), 38-43

[18]. **Rosebery, A.S. & Rubin, A. (1989).** Reasoning Under Uncertainty: Developing Statistical Reasoning. *Journal of Mathematical Behavior*, *8*, 205-219.

[19]. **Savoldelli, G., Naik, V., Hamstra S. & Morgan, p. (2005)** Barriers to use of simulation-based education, *Can J Anaesth*, *52*, 944-950.

[20]. **Segenchuk, S. (1997).** *The Role of visualization in education.* Retrieved 6/12/2008: http://web.cs.wpi.edu/~matt/courses/cs563/talks/education/IEindex.html

[21]. **Smith, B. (2003).** Using and Evaluating Resampling Simulations in SPSS and Excel. *Teaching Sociology*, *31*(3), 276-287.

[22]. **Structural Informatics Group (2007).** *Digital Anatomist Project.* Retrieve 6/12/2008: http://www9.biostr. Washington.edu/da.html

[23]. **Tversky, B., Morrison, J. B., & Betrancourt, M. (2002).** Animation: Can it facilitate? *International Journal of HumanComputer Studies, 57*, 247-262.

[24]. **Vekiri, I. (2002).** What is the value of graphical displays in learning? *Educational Psychology Review*, *14*(3), 261-312.

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