Abstract

The utilization of visual elaboration has been a key component of the educational process for instructors of agricultural power technology. Traditionally, still illustration and representatives of real equipment (realia) have been utilized to teach the hidden theoretical concepts that comprise the most basic operational processes of the internal combustion engine and its accompanying systems. Exponential technology advancement has allowed the development of a new mode of visual elaboration in the form of high-quality computer-generated animation. This study, which is one part of a larger study, investigated the affects of computer-generated animations on low-level cognition in undergraduates. The dual-coding theory was utilized as the investigation’s theoretical framework. Computer-generated animations are most effective when used with topics that are abstract, vague, hidden or too fast or slow to view. When applied to operational theory of common internal combustion engines, animation is a natural fit. The study utilized an experimental pretest posttest control group design. Participants were undergraduate students (n=47) enrolled in “Agricultural Power Units”, an undergraduate agricultural power technology course at a university in Texas. Following pretest and immediate posttest, a delayed posttest was administered in order that learning decay could be measured. For this investigation, the dependent measure, (multiple choice test) consisted of low-level cognitive questions only. Two hypotheses were developed. Results indicate that no significant differences existed between the traditional and animated groups. The authors call for replication and further study of the utilization of animation in agricultural mechanization topics.
Introduction/Theoretical Framework

Teaching courses related to agricultural mechanization has always required instructors to put forth rather substantial amounts of effort and creativity, especially for topics which cannot be conveniently viewed. Agricultural power technology is one such topic area that restricts instructors because many of the systems’ processes are hidden from view or occur at such great speeds, students are not able to study the mechanical concepts and relationships taking place. This includes concepts or content that may be abstract, vague, hard to visualize, too fast or slow to see, or hidden from view, hence, they are abstract concepts in the student's mind (Gagné, 1985).

The use of still pictorial representations, specialized learning aids, machinery cutaways and actual parts have all been integral weapons in the agricultural power instructor’s arsenal for combating the phenomena of the speedy or unseen in the topics they teach. Unfortunately, static illustrations do not fully represent this process and the purchase of actual agricultural power equipment for the sole use of instruction is not a viable solution because of the cost of acquiring such equipment and keeping equipment that is technologically current. Furthermore much time and expense must be devoted to many of these teaching aids that can be bulky and may still not deliver the desired learning effects.

New advances in the area of computer-generated animation may be one of the tools that aids student learning in such topics as agricultural power, while relieving some of the monetary and time constraints that are consistent with traditional methods of visual lesson reinforcement. Although much of the research conducted on the benefits of animation in a learning environment is not consistent (Park & Hopkins, 1993; Rieber, 1990a), many students favor and enjoy learning with animation (Rieber, 1990b, 1991; Rieber, Boyce, & Assad, 1990; Dooley, Stuessy, Magill, & Vasudevan, 2000).

A computer-generated animation is a series of still computer generated pictures that are presented in succession in order that the illusion of motion is developed, much like a picture flip-book (Burke, Greenbow, & Windschitl, 1998). Animations differ in that they offer two unique attributes that still pictures do not, trajectory and motion (Rieber, 1991). Therefore, animations represent a subset of instructional visuals (Rieber, 1990a) and receive general theoretical support from information processing learning theories purported by individuals such as Gagné (1985) and Paivio (1971, 1983, 1986, 1990).

Animations tend to aid in high-level cognition situations such as problem solving, incidental learning, critical thinking, etc, rather than aiding students in low-level recall (Baek & Layne, 1988; Agnew & Shinn, 1990; Rieber, 1990a; Rieber, Boyce, & Assad, 1990; Mayer & Anderson, 1991, 1992; Park & Hopkins, 1993; Williamson & Abraham, 1995; Nicholls, Merkel, & Cordts, 1996). According to Park and Hopkins (1993) if a lesson is limited to low-level learning tasks, animations have the same effect as still illustrations. We also know from the literature that animations are specialized and must be used in the correct context, situation, and the appropriate philosophical perspective, (Rieber & Hannafin, 1988; Rieber, 1990a; 1990b; 1991; LoPresti & Garafalo, 1992; Park & Hopkins, 1993; Williamson & Abraham, 1995; Nicholls, Merkel, & Cordts, 1996; Dooley, Stuessy, Magill, & Vasudevan, 2000) as well as with the appropriate
Primary theoretical support for the use of animations, as well as still illustration, and their effects on learning comes from the dual-coding theory (Pavio, 1971, 1983, 1986 & 1990). According to this theory, information is processed and represented by two separate codes known as verbal codes and non-verbal codes. The theory argues that humans understand the world around them through language and non-verbal objects and occurrences. Language is categorized as incoming and outgoing and shares a symbolic relationship to the non-verbal, which can be representative of such things as objects, events, and behaviors. The non-verbal code includes all information that can be processed from the senses, which includes non-verbal sounds. These verbal and non-verbal codes can be encoded information from a human’s environment individually or simultaneously.

Verbal and non-verbal coding systems work as a sort of two-lane road in which information travels. As information travels along this roadway many connections are developed during the process of cognition. As information is acquired, representational connections are made to verbal or non-verbal information received by the learner. These connections are exactly as their name implies, they are representative schema that activate prior knowledge or experiences that the learner may have in relation to what is being learned. For example, if a student views a brightly colored rubber orb, the structure is representative of a ball used for play, representation is developed between what is experienced by the senses and the individual’s sense representation for what is experienced. Associative connections are made within the verbal and non-verbal “lanes,” respectively, that is, actual words and an individual’s verbal representations of the words are developed and connected, also words that may be associated to one another tend to make connections as well (i.e., the word tabby may also activate the word feline). Non-verbals are also connected associatively, just as with words, smells may conjure visual memories or the sight of certain objects may cause flashbacks to scenes experienced by an individual. Put simply, associations are made, and words are related to other words and images to other images of the same or different sense perception mode (Pavio, 1971, 1986; Clark & Pavio, 1991). The third types of links are referential connections, which are connections that crossover “lanes” in order to create links between the verbal and non-verbal information. These types of connections are
championed by supporters of multimedia instruction for the argument that if information is coded verbally, as well as through another sense such as sight (visually), the information is more likely to be remembered because one representation or reference can activate another. “When information is dually coded, the probability of retrieval is increased because if one memory trace is lost, another is still available” (Rieber, 1991, p. 319). Figure 1.1 is a visual representation of the dual-coding theory.

Current research indicates that animation tends to have a cognitive orientation, therefore a low/high-level cognitive orientation was implemented (Baek & Layne, 1988; Agnew & Shinn, 1990; Rieber, 1990a; Rieber, Boyce, & Assad, 1990; Mayer & Anderson, 1991 & 1992; Park & Hopkins, 1993; Williamson & Abraham, 1995; Nicholls, Merkel, & Cordts, 1996). The effect of simulation on retention and delayed testing was investigated in a study conducted by Agnew and Shinn (1990). The researchers did not utilize animations, rather simulation activities were utilized as an independent variable. The study served as insight for this investigation because of limited investigation into delayed testing application. Dual-coding theory offers implications for the use of animations because of the development of referential connections, which offer a greater probability of information recall following differentiating time lapse (Paivio, 1990; Rieber, 1990a). Therefore, this portion of a larger study focused on animation effects on immediate and delayed posttests for low-level cognition.

**Purpose and Hypotheses**

The purpose of the study, which was a part of a larger study, was to determine if any measurable learning effects would result from the use of computer generated animations as an added visual display on an immediate and delayed low-level cognitive posttest. Undergraduate students enrolled in the course were studied in order to determine if significant differences existed between students who view computer-generated animations that were added to the traditional
barrage of visuals, in comparison to students who viewed only the traditional visual tools. Consequently, the following research hypotheses were formulated:

H₀₁: There is no significant difference between the illustration/realia (traditional) group and the illustration/realia/animation (animation) group on the immediate low-level cognitive test scores.

H₀₂: There is no significant difference between the illustration/realia (traditional) group and the illustration/realia/animation (animation) group on the delayed low-level cognitive test scores.

Methodology

The research design selected for this study was an experimental, randomized subjects, pretest-posttest control group design (Ary, Jacobs, & Razavieh, 1996). Rationale for selection of this design does exist because random assignment of subjects to experimental treatment was possible even though the subjects were self-selected into a particular course (Kirk, 1995; Ary et al., 1996; Gay & Airasian, 2000).

The population consisted of undergraduate students in Colleges of Agriculture whose major course of study requires an agricultural power course and/or students that may have a particular interest in an agricultural power course. Students self-selected themselves for the study by registering for Agricultural Engineering 2013 – Agricultural Power Units, which is offered every fall and spring semester of the year. A self-selected sample (n=56) was utilized for this experiment. The number of valid scores available following the delayed posttest was n=47. No significant differences existed between the animation and traditional groups.

The data were collected during the fall semester 2002, during the fourth week of classes. The study was conducted over four weeks. The actual experiment took place during one instructional week. Pretest was administered two weeks prior, and the delayed posttest one week following each of the instructional units. Pretest and posttest questions were identical, but pretest question order was different from that of the posttests. Both groups participated at 9:25 a.m., the regularly scheduled class time. Upon entering the classroom, subjects participated in the class as they normally would. The participants were asked to attend to the material in the lesson and take notes as they wanted. Participants were also informed of the immediate posttest that followed the lesson. Each lesson for the traditional and animation groups lasted approximately two hours, this included instructional and testing time.

A lecture-style presentation was delivered to participants in both groups. Lecture content focused on the operational theory of spark ignition and compression ignition internal combustion engines. Students in the treatment (animation) group viewed a Power Point® presentation supplemented with illustrations and animations inserted into the presentation, realia (actual engine parts/cutaways) were also be utilized in this group. The control (traditional) group also viewed a Power Point® presentation covering the same material, differentiating only in the fact that additional illustrations were inserted into the presentation where animations were for the treatment group, realia was also utilized.
Upon completion of the lesson content a thirty question multiple-choice test was administered to each participant. This administration served as the immediate posttest. Participants had as much time as needed to complete the posttest. Exactly one-week following the immediate posttest, each group was administered the delayed posttest.

The instrument was a researcher-developed test that coordinated with the lesson’s content and material. The overall instrument’s item content varied according to high and low cognitive levels according to the levels of cognition developed by Newcomb and Trefz (1987), which were adapted from Bloom’s Taxonomy. Newcomb and Trefz consolidated Bloom’s Taxonomy into four levels of cognition, which are, remembering, processing, creating and evaluating. The current study utilized the low-level cognitive questions only. Originally, fifteen of the instrument’s items were low cognitive level questions, which students were required to utilize remembering and processing skills. Each of these fifteen questions came directly from the lesson material. Test items classified as low-level cognitive questions were directly taught during the instructional setting, therefore students needed only to recall information in order to be successful on each low-level question.

The instrument was tested for face and content validity by a national panel of experts in agricultural education, agricultural mechanization, and agricultural engineering whose research areas have focused on agricultural mechanization/engineering, cognitive levels for testing and educational objectives. The overall reliability of the test was measured by the Kuder-Richardson-20 (KR-20) formula upon completion of the immediate posttest. Initial reliability coefficients for the overall pretest (.25) and overall immediate posttest (.54) were unacceptable.

Initially, Bartlett’s Test of Sphericity was conducted on the overall test to determine if the test item correlation matrix was indeed an identity matrix (Bartlett’s test – chi-square (66) ~121.90, p < .01), and a principal components analysis was conducted to determine the underlying constructs among the low-level, high-level, and total test questions. The principal components analysis was followed by a varimax orthogonal rotation to determine the underlying reliable question concepts that the researcher-designed instrument measured. Subsequently, six factors were extracted from the overall test based on eigenvalues greater than one and an in-depth analysis of the scree plot. The six factors explained approximately 75% of the variation among the thirty multiple-choice items.

A second principal component analysis was followed by a varimax orthogonal rotation to determine the underlying reliable question concepts that the researcher-designed instrument measured for the low-level cognitive questions. Subsequently, three factors were extracted based on eigenvalues greater than one and an in-depth analysis of a scree plot. The three factors explained approximately 74% of the variation among the low-level cognitive multiple-choice items (See Table 1).
Table 1
Results of Principal Components Analysis Conducted Among Low-Level Test Questions

<table>
<thead>
<tr>
<th>Concept Measured</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differentiation of Valve Mechanisms</td>
<td>.875</td>
<td>.832</td>
<td></td>
</tr>
<tr>
<td>(Low Level)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner Cylinder Gas Flow Related to Design</td>
<td>.871</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Low Level)*</td>
<td></td>
<td>.714</td>
<td></td>
</tr>
<tr>
<td>Two-Stroke SI &amp; CI Intake Stroke Comparisons</td>
<td></td>
<td>-.687</td>
<td>.671</td>
</tr>
<tr>
<td>(Low Level)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eigenvalues</td>
<td>2.20</td>
<td>1.14</td>
<td>1.11</td>
</tr>
<tr>
<td>Percentage of Variance Explained By Each Factor</td>
<td>36.61</td>
<td>18.99</td>
<td>18.47</td>
</tr>
<tr>
<td>Cumulative Percentage of Variance Explained By Each Factor</td>
<td>36.61</td>
<td>55.60</td>
<td>74.07</td>
</tr>
</tbody>
</table>

Table 1 indicates that factor 1 accounted for 36.61% of the variance, while factor 2 accounted for 18.99% and factor 3 accounted for 18.47% of the total variance. All low-level questions loaded as factors in the same manner as in the overall principal components analysis.

According to Stevens (2000), factor loadings greater than .5 for the current population are declared statistically significant at the .05 level. Following these recommendations, the current varimax loadings indicate the presence of three distinct concepts related to varying operational theories of all internal combustion engines presented.

Following the principal components analysis, reliability estimates were run on the questions that were represented in the final three-factor low-level solution. The resulting Kuder-Richardson-20 (KR-20) reliability coefficient for the low-level cognition posttest questions was .62. Finally, it is noted that researcher-developed instrumentation to instructional content is commonplace in animation research. Furthermore, the adjustment of such tests is evident in the reviewed literature because of the realistic nature of the research (multiple-choice test following a lesson), small sample sizes and low question frequency (Rieber, 1990a, 1990b; Rieber, Boyce, and Assad, 1990; Mayer, 1997; Mayer & Anderson, 1991, 1992).

Upon completion of each of the three rounds of testing, data were entered into and analyzed using SPSS for Windows®. Descriptive data were collected and include immediate and delayed posttest scores, gender, GPA, and classification. All descriptive data were analyzed and presented in the form of counts, percentages, means, and/or standard deviations.

Mean comparisons were made utilizing an analysis of variance for both hypotheses. As mentioned previously, the final number of scores available for analysis was $n=47$, therefore, the control (traditional) group ($n=24$) and the treatment (animation) group ($n=23$) were still unequated when considering frequency. According to Green, Salkind, and Akey (2000), if cell sizes are not equal, it is suggested that un-weighted means (estimated marginal means) be reported in the results. Both null hypotheses were tested at the $p < .05$ level.
Results/Findings

Following analysis of all valid cases, it was found that 34 participants were male (72.3%) and 13 (27.6%) were female. The average age of the participants was 20.5 years (SD= 3.78) and the average cumulative GPA for all participants was 2.62 (SD=.55) on a 4.0 scale. Of the students who participated in the study, 25% were freshmen, 39.3% were sophomores, 12.5% of the participants were juniors, and 10.7% were seniors.

Table 2 reports the estimated marginal mean scores, standard error, and confidence intervals for each testing administration during the course of the experiment for the traditional (control) and the animation (treatment) groups.

Table 2
Summary of All Low-Level Testing Administrations to Participants

<table>
<thead>
<tr>
<th>Test Administration</th>
<th>Traditional Group</th>
<th>Animation Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EMM</td>
<td>SE</td>
</tr>
<tr>
<td>Low-Level Pretest</td>
<td>25.3</td>
<td>3.43</td>
</tr>
<tr>
<td>Low-Level Immediate Posttest</td>
<td>74.3</td>
<td>4.80</td>
</tr>
<tr>
<td>Low-Level Delayed Posttest</td>
<td>63.9</td>
<td>5.14</td>
</tr>
</tbody>
</table>

EEM – Estimated Marginal Mean  
SE – Standard Error

Hypothesis One

Hypothesis one tests the hypothesis of no differences between traditional and animation groups for the immediate posttest. Table 3 summarizes the results of an analysis of variance utilized to test the hypothesis of no differences.

Table 3
Analysis of Variance Comparing Traditional and Animation Groups on Immediate Low-Level Cognitive Posttest Scores

<table>
<thead>
<tr>
<th>Group</th>
<th>M</th>
<th>SD</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>74.3</td>
<td>4.80</td>
<td></td>
<td>1</td>
<td></td>
<td>2.670</td>
<td>.109</td>
</tr>
<tr>
<td>Animation</td>
<td>63.0</td>
<td>4.90</td>
<td>1474.97</td>
<td>1</td>
<td>1474.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24855.46</td>
<td>45</td>
<td>552.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>26330.43</td>
<td>46</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Although the traditional group (M=74.3, SD=4.80) did score higher on the immediate low-level posttest in comparison to the animation group (M=63.0, SD=4.90), no significant differences were detected. This finding was surprising, especially when taking into account the animation group’s slight advantage on pretest and GPA variables. Nevertheless, according to the non-
significant *F*-ratio, the addition of animated visuals did not significantly affect learning when compared to the traditional method of instruction.

**Hypothesis Two**
Hypothesis two tests the hypothesis of no differences between traditional and animation groups for the delayed posttest. Table 4 summarizes the results of an analysis of variance utilized to test the hypothesis of no differences.

**Table 4**
Analysis of Variance Comparing Traditional and Animation Groups on Delayed Low-Level Cognitive Posttest Scores

<table>
<thead>
<tr>
<th>Group</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>63.9</td>
<td>5.14</td>
</tr>
<tr>
<td>Animation</td>
<td>57.9</td>
<td>5.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>417.46</td>
<td>1</td>
<td>417.46</td>
<td>.658</td>
<td>.422</td>
</tr>
<tr>
<td>Within</td>
<td>28554.45</td>
<td>45</td>
<td>634.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>28971.92</td>
<td>46</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Although the traditional group (M=63.9, SD=5.14) did score higher on the delayed low-level posttest in comparison to the animation group (M=57.9, SD=5.25), no significant differences were evident. This finding was consistent with the immediate low-level cognitive examination. Also, the consistency of no-difference between groups on a delayed measure is consistent with the findings of (Agnew & Shinn, 1990). According to the non-significant *F*-ratio, the addition of animated visuals did not significantly affect learning when compared to the traditional method of instruction.

**Conclusions/Recommendations**

**Hypothesis One**
The results from this study indicate the addition of animation to an agricultural power lesson did not significantly affect low-level cognitive understanding for students viewing animation as compared to students who did not view animation when measured on an immediate posttest. Although no significance was detected, an interesting inter-group consistency developed between the traditional and animation groups. Participants in the traditional group outperformed their counterparts in the animation group on the immediate low-level cognition posttest measure. This lesser finding is consistent with prior research that has found that, typically, no differences exist between animation and illustration/reali when considering low-level recall information (Mayer, 1989; Rieber, 1990a, 1990b, 1991; Rieber, Boyce, & Assad, 1990; Rieber & Kini, 1990; Mayer & Anderson, 1991, 1992; Park & Hopkins, 1993). If asking students to perform simple tasks related to remembering and processing (Newcomb & Trefz, 1987), still illustrations and realia are just as effective as computer-generated animation coupled with still illustrations and realia. This finding may be further reinforced by the findings of Park and Hopkins (1993), who found that static visual displays that imply motion are just as effective as animated visuals. All of the still illustrations in this investigation implied motion.
**Hypothesis Two**
The results from this study indicate the addition of animation to an agricultural power lesson did not significantly affect low-level cognitive understanding for students viewing animation as compared to students who did not view animation when measured on a delayed posttest. This finding was consistent with the findings of Agnew and Shinn (1990), because low-level learning decay was not dramatically different for either group. Although no significance was detected, another interesting inter-group consistency developed between the traditional and animation groups. Participants in the traditional group outperformed their counterparts in the animation group on the delayed low-level cognition posttest measure. This finding, as above, is consistent with prior research that has found that, typically, no differences exist between animation and illustration/realia when considering low-level recall information (Mayer, 1989; Rieber, 1990a, 1990b, 1991; Rieber, Boyce, & Assad, 1990; Rieber & Kini, 1990; Mayer & Anderson, 1991; Mayer & Anderson, 1992; Park & Hopkins, 1993). It is noted however, that the mean difference between groups for the delayed low-level posttest was not as dramatic in comparison to the mean difference between groups for the immediate low-level posttest.

If asking students to perform simple tasks related to remembering and processing (Newcomb & Trefz, 1987), still illustrations and realia are just as effective as computer-generated animation when paired with still illustrations and realia on an immediate or delayed posttest. This finding is also reinforced by the findings of Park and Hopkins (1993), who found that static visual displays that imply motion are just as effective as animated visuals. Once again, all of the still illustrations in this investigation implied motion.

**Discussion**
The authors would like to advise the readers to approach the findings of this study with caution. Findings were based upon a subset of students from a limited geographical location in the United States. Also, generalizability could also be limited due to the study’s small sample size and limited available population.

Although no significant differences existed, an immediate observation can be made that on both the immediate and delayed low-level cognition scores the traditional group’s performance was better than the animation group. This tends to support prior research.

The current study has found that educators involved in the instruction of agricultural power topics cannot expect significant learning effects, negative or positive, from the addition of computer-generated animation to their lessons. The addition of animation to traditional teaching methods did not affect low-level cognition, nor did it affect learning decay.

The authors would like to recommend that this study be replicated to determine if the current study’s findings are consistent. Replications should take place in related fields in different portions of the United States and abroad in order to detail the effects of animation on such a topic in agricultural power technology. Also, replications should be performed with larger samples with dependent measures that are objective in nature, this reflects the reality of our current higher education system. Steps have already been taken by the authors to perform an exact replication of the current study in order to validate results. It is also recommended that the current study be replicated with high school agricultural science students across the state and nation. Pressley...
(1977) promoted the position that adult learners with preset mental models for understanding tend not to rely on visual stimulation through the learning process as much as young learners. Finally, the authors would like to call for additional research with different combinations of illustration, realia and animation. Additional research will lead to a deepening in understanding that will add to the current and related disciplines.

References


