Effects of Distributed Practice Theory on Arc Welding Skill Development of Agriculture Students

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The cluster curriculum approach to teaching exploratory skills in vocational agriculture (Alabama Board of Education, 1986; Oklahoma Board of Education, 1972) is utilized by several states. This cluster approach makes more efficient use of the instructor's and student's time. This, then, provides the students more opportunities for hands-on experiences in the broad and related fields of agriculture prior to making a firm career commitment. Three shop skill areas often clustered are arc welding, basic woodworking and small gasoline engine repair.

Alabama alone has some 8,367 students in this cluster program for which five hours of practice time in arc welding is recommended. Yet, no scientific basis has been established to recommend a time interval structure for maximum utilization of this recommended practice time for student acquisition of elementary welding skills.

Research in the cognitive domain (Cook, 1934; Oseas & Underwood, 1952; Thorndike, 1932) supports the theory that distribution of practice was more effective--at least for retention--than massed practice. Based on this research, Hovland (1940) proposed a theoretical position for the superiority of distributed practice over massed practice not only for retention but also for acquisition. He theorized that performance depends upon the positive learning minus the strength of the interfacing process (inhibitory effects) and that the interfering tendencies decrease in strength with the passage of time more rapidly than do positive learning tendencies.

Utilizing young and adult farmers, Shinn (1971) sought to determine the effects of course duration on the motor skill development of three complex arc welding tasks. His conclusions were that: (a) three course durations did not significantly affect arc welding performance of adults on a complex motor skill task, and (b) performance on three arc welding tasks was not significantly affected by the use of three ratios of practice time.

Yet, research by Schendel (1979) and Shea and Morgan (1978) tends to support the theory of distribution of practice in the psychomotor domain, coinciding with the generally accepted theoretical constructs associated with cognitive learning. With psychomotor research still in its infancy in vocational agricultural education and with the larger numbers of students in America in secondary vocational agricultural education programs, there is a need to examine the effects of distributed practice in the development of exploratory arc welding skills.

Purpose

The purpose of this study was to compare the effects of three different distributions of welding practice time intervals on the quality of welds made by ninth grade vocational agricultural education students.

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The following null hypothesis was formulated and tested at an alpha level of .05:

> The main effects of distributed practice time, 15, 30, and 45 minutes (independent variable), would not significantly influence the quality of butt welds as measured by tensile strength test (dependent variable).

Method

This study utilized a posttest-only experimental design involving three groups (N = 48). This design was utilized, as recommended by Campbell and Stanley (1966), due to the initial introduction of new material or experiences for which pretests in the ordinary sense are impossible or inappropriate. An equal number of subjects (16) were randomly assigned to each group, with random assignments to treatments.

The population consisted of 48 randomly selected first-year vocational agricultural education students from a secondary school system in central Alabama. The all male population was 16.7% non-white and represented the following age levels: 14 years (54.4%), 15 years (31.3%) and 16 years (14.2%). No subject reported previous hands-on experience in arc welding.

The tensile strength test was used as instrumentation for the study. Althouse, Turnquist, and Bowditch (1967) reported that techniques for evaluating quality of welds fall into two classifications, destructive and nondestructive tests. The tensile test, a destructive test, mechanically determines certain characteristics of the weld as the weld is subjected to a slowly applied force tending to pull it apart. One primary weld characteristic determined by this process is the tensile strength, measured in pounds per square inch. Tuttle (1966) defines tensile strength as "that property which enables a material to withstand a stress without fracturing or suffering permanent deformation."

The tensile test machine, manufactured by Tinius Olsen Company, Willow Grove, Pennsylvania (Series #62548), in Auburn University's Mechanical Engineering Department, mechanically pulled the welds apart to determine their tensile strength in pounds per square inch. The Tinius Olsen Company, under contract to Auburn University, had recently calibrated the machine to ensure its reliability.

Subjects were introduced to basic content materials on arc welding for five hours prior to beginning the interval welding practice sessions. Recommendations of the James F. Lincoln Arc Welding Foundation developed by Sellon and Matthews (1963) were followed for content and instructional procedures. The following basic subject matter content material was covered: (a) The Development of Arc Welding, (b) How Arc Welding is Used, (c) Arc Welding Equipment and Supplies, (d) Learning to Weld, (e) Weaving and Padding, (f) Making Welds in Downhand (flat) Position, and (g) Making Butt Welds.

Once subjects were exposed to the content material, they were taken to the welding laboratory for demonstrations. The demonstrations included sessions on safety, use of equipment and accessories, setting the amperage, preparing to weld, striking the arc, running the bead, restarting an interrupted bead, recognizing a good bead, weaving, padding, and making a butt weld.

Each subject participated in a 15-minute supervised practice session prior to the initial timing of the interval practice sessions.

This practice session consisted of practice on (a) striking the arc and (b) running a weld bead. Subjects then maintained rigid practice schedules, with all three groups receiving a total of five hours of practice time.

Groups I, II and III practiced welding 15, 30 and 45 minutes, respectively, each school day until they obtained their full five hours of practice. After three full hours of practice on laying beads and restarting interrupted beads, their practice also included making butt welds. Three Nick-Break tests were conducted on the subjects' welds, and each was evaluated. Shinn (1973), in recommending use of the Nick-Break test, concluded that practice without the knowledge of results has appeared to have very little effect upon individual performance. After each subject completed the five hours of required practice time, a two-minute practice session was allowed before making the test butt weld the following day.

The Lincoln 225 amp, AC welding machines and E-60/13 welding electrodes were utilized. Test metal for the butt weld was two pieces of 3/8" x 3" x 6" mild steel metal of approximately 60,000 pounds of tensile strength per square inch. The test butt weld was made in the flat (down-hand) position by placing the two pieces of metal end-to-end and making a 3-inch butt weld on one pass.

The null hypothesis for the study was analyzed using a one-way analysis of variance. Duncan's New Multiple Range Test was utilized to identify mean differences. The hypothesis was tested at an alpha level of .05. The SPSS (1983) programs were used to statistically analyze all data reported in the study.

Results

The main effects of treatment (15-, 30- and 45-minute distributed practice intervals) and their interaction on the tensile strength test when tested utilizing a one-way analysis of variance are illustrated in Table 1.

Table 1

Analysis of Variance Results for Data Involving the Effects of Distributed Practice Intervals on the Tensile Strength Test

Source	DF	SS	MS	F Ratio	F Prob.
Between	2	1,383,214,103.56	691,607,040.00	5.40	.0079
Within	45	5,760,952,320.00	128,021,152.00		
Total	47	7,144,165,376.00			

Utilizing the analysis of variance procedure, a significant difference was demonstrated among the effects of the three levels of the independent variable (15-, 30- and 45-minute distributed practice intervals) on the dependent measure, the tensile strength test, $F(2, 45) = 5.40$,

p = .0079. The tensile strength test means, in pounds per square inch, for the 15-, 30- and 45-minute distributed practice interval groups were 21,187.50, 16,718.81 and 15,062.50, respectively. The means and standard deviations are illustrated in Table 2.

Table 2

Mean Scores and Standard Deviations of Tensile Strength Test by Distributed Practice Time Intervals

Distributed Practice Time Intervals	Number	Tensile Strength Test[a]	
		Mean	S.D.
15 minute	16	27,187.50	7,066.05
30 minute	16	16,718.81	16,428.79
45 minute	16	15,062.50	8,014.30

[a]Tensile strength test scores in pounds per square inch.

Duncan's New Multiple Range Test, utilized to identify mean differences, revealed significant differences among the means. The means for the 15-minute practice interval ($\overline{X}$ = 27,187.50) were significantly higher than those for the 30-minute practice interval ($\overline{X}$ = 15,062.50). Means for the 30-minute practice interval and the 45-minute practice interval did not differ significantly.

Results indicated a rejection of the null hypothesis. Therefore, the main effects of distributed practice time intervals of 15, 30 and 45 minutes did significantly influence the quality of butt welds made by ninth grade vocational agriculture students as measured by the tensile strength test.

Conclusions

The conclusions drawn from the study, as to the result of the tensile strength test, appear to indicate that with the same total practice time, different distributions of welding practice time intervals influence the quality of butt welds made by ninth grade vocational agriculture students. Results of the mechanical tensile strength test revealed a definite superiority of the 15-minute distributed practice time interval for the acquisition and performance of elementary arc welding skills over the 30-minute and 45-minute practice times.

Shinn's (1971) conclusions, that performance on three arc welding tasks were not significantly affected by three rations of practice time, are somewhat contradicted. However, Shinn's study was designed around three course durations and three ratios of classroom instruction and practice time. Course durations were comprised of: (a) three two-hour classes, (b) five two-hour classes, and (c) ten two-hour classes. Practice ratios included (a) a ratio of 75% practice time to 25% classroom instructional time, (b) a ratio of 50% practice time to 50% classroom instructional time, and (c) a ratio of 25% practice time to 75% classroom instructional time. Differences in findings by Shinn and this study might have occurred as a result of three basic differences in the studies: (a) number of tasks performed, (b) complexity of tasks performed, and (c) pedagogy versus androgogy learning.

Hovland's (1938) theory and explanation of more rapid acquisition of cognitive information by distributed practice appears to offer some explanation for the differentiated welding performance, in the psychomotor domain, of the acquisition and performance of arc welding skills. As Hovland suggested in the cognitive learning domain, the longer practice sessions (30 minutes and 45 minutes) probably allowed fatigue to set in and mask the extent of learning or performance. Also, probably for the cognitive learning domain, the rest pauses allow for the incorrect associations to weaken more rapidly than the correct associations, because of the differential strength of the incorrect (interfering associations) and correct associations. Edwards and Scannell's (1969) research supported this position and suggested that the intervals associated with distributed practice are helpful because the error tendencies in response acquisition will be great, and the time intervals allow, through other factors, a recovery of error tendencies so that subsequent correct responses extinguish such error.

Also, the 15-minute distributed practice intervals involved an increased number of periodic recall and performance events after no-practice intervals, a situation Hovland concluded enhanced acquisition and retention. This would aid in explaining the net gain or significant gain in acquisition and performance of welding skills of the group in the 15-minute distributed practice interval.

The following implications are offered as a result of this study and subsequent discussions. The theoretical assumptions supporting distribution of practice concepts associated with learning in the cognitive domain appear to extend to the psychomotor domain. There is a need for research to ascertain if these basic concepts can be supported in skill development areas other than arc welding. Also, additional research is needed to ascertain if the law of diminishing returns has an effect on performance in the psychomotor domain, and, if so, at what distributed practice intervals it occurs. It appears that the distributed practice intervals of 15 minutes are most appropriate in the development of elementary welding skills if the primary concern is focused on high tensile strength welds.

Additional research is needed relating to classroom management and organization of learning experiences around the cluster concept. This should be done to determine the most beneficial acquisition and performance time intervals for organizing and managing practice time intervals for maximum skill acquisition. This should allow more justifiable tailoring of daily classroom experience for students. It is only through research and implementation of the findings that maximum exposure to content and hands-on experiences, use of resources, and benefits from the principle related to acquisition of learning and performance through distributed practice can be achieved.

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