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Dexterity: An Indicator of Future Performance in Beginning Welders?

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Abstract

This study examined the use of dexterity to indicate future performance of beginning welders to select participants for welding training programs. With a high demand for welders, it is imperative that welding training programs be efficient, which can be time consuming (Stone, Watts, & Zhong, 2011). The time required to train certified welders is one of the obstacles training programs face. Many occupational fields have tried to predict a student’s future performance before admitting them into a training program by analyzing their dexterous ability. This study utilized the Complete Minnesota Dexterity Test (CMDT) to examine participants’ dexterity during a welding training program. At the end of the training program, participants performed tests welds that were overseen by a certified welding instructor (CWI) who visually inspected each weld. The data from the dexterity tests and the pass/fail rate of the test welds were analyzed using Predictive Analytics SoftWare (PASW) Statistics 18 software package. All three dexterity tests were found to have statistically significant relationships with the visual pass/fail rates of the participants for basic shielded metal arc welds (SMAW). It can be concluded that dexterity can predict future performance of beginning welders completing basic SMAW welds.

Introduction

Due to a global boom in the industrial manufacturing sector welders are in greater need now than ever before (Brat, 2006). According to the U.S. Department of Labor, Bureau of Labor Statistics (2012), the number of jobs for welders is expected to increase 15% from 2010 to 2020, which is as faster than all other occupational fields reported. Welding is a technical skill that requires its practitioners to be certified, which takes time, money, and talent (Stone, Watts, & Zhong, 2011). The time that is needed to train a person to become certified to weld is one of the areas that many welding educators have tried to shorten. According to Giachino and Weeks (1985), for a skilled manual welder to master the craft requires years of on-the-job training. It is this concern, expressed by many companies, of extensive training after recruitment and the failure of trainees to achieve acceptable standards that have led to the high interest in trainability testing (Hitchings & Moore, 1991).

Since its inception, welding training programs have been continually evolving to better prepare welders. Weld trainers have incorporated several computer-based advancements into their programs such as virtual reality simulators (Byrd & Anderson, 2012). Simulations have been used in several occupational fields such as medical, dental, and welding to train students to become proficient at various skills (Boulet et al., 2003; Kunkler, 2006; Papadopoulos, Pentzou, Louloudiadis, & Tsiatosos, 2013; Stone et al., 2011) The use of virtual reality simulators have helped increase the awareness of welding to the younger gaming generation (Postlethwaite, 2012). With a majority of learning and interaction occurring in a digital environment virtual reality simulators creates an avenue to recruit new students (Lincoln Electric, 2013). With this
influx of newcomers to training programs is there a way to predict which people will have the best capability to weld?

Many occupations have tried to predict a student’s ability of future performance prior to admitting them into a training program. The typical tests that have been utilized to predict future performance analyze cognitive ability, psychomotor skills, and perceptual tests (Gettman et al., 2003; Levine, Spector, Menon, & Narayanan, 1996; Hitchings & Moore, 1991; Brown & Ghiselli, 1951). Dental and surgical training programs have conducted studies examining how effective these aptitude tests are at predicting future performance. A study by Gettman et al. (2003) shown that the measures of innate ability were able to accurately predict the future performance of 65% of laparoscopic surgeons (N=20). Gansky et al. (2004) found that manual dexterity was able to predict future performance of dental students in subsequent preclinical restorative courses.

One factor that has been studied to examine the ability to predict future performance is dexterity. According to Campbell (2007), dexterity is the skill of using one’s hands and body, which addresses the quickness or the coordination of sight, and other senses, with muscles. Dexterity has been validated in predicting performance in jobs that require routine assembly, coil winding, and packaging than on jobs that require higher order abilities (Hitchings & Moore, 1991; Levine et al., 1996; Mansell, 1969). Because welders are required to routinely perform many welds that require higher order thinking skills to complete can dexterity be able to predict performance in a welder?

Welding literature has stated that welders need manual dexterity, good eyesight, and good hand-eye coordination (Giachino & Weeks, 1985; Jeffus, 2012; Jeffus & Bower, 2010a). Giachino and Weeks (1985) also stated that welders need the ability to concentrate on detailed work, be free of disabilities that would prevent work in awkward positions. To evaluate these criteria welder training programs have employed tests that evaluate mechanical ability, ability to judge shapes and sizes, remember designs, and manual dexterity when selecting apprentices (Fleming, 1937), but have not extensively evaluated the predictive ability of individual factors for future performance.

Mansell (1969) stated that technical teachers are mostly concerned with trainee knowledge and dexterity. Mansell (1969) also stated that to teach dexterity of a skill an analysis of the skill must first be completed because every skill has sub-skills that must also be known. Using dexterity and trainability testing techniques require the tests be designed around the skills of the particular job being studied (Hitchings & Moore, 1991).

A few of the welding parameters that a welder is required to maintain during the welding process are arc length, weld position, travel angle, work angle, and travel speed (Jeffus, 2012; Jeffus & Bower, 2010a). These parameters are crucial in order for the welder to correctly weld two pieces of material together. In the process of shielded metal arc welding (SMAW), also known as arc or stick welding, these parameters are always in a state of flux (Jeffus, 2012). The state of flux is created by the welding electrode being consumed during the welding process (Jeffus, 2012). This requires the welder to maintain the correct position, angles, and travel speed all while slowly feeding the electrode downward to maintain the correct arc length. The other aspect of welding that increases the need of manual dexterity is the use of weave patterns. The
manipulation of the electrode, weaving, can help control penetration, width, porosity, undercut, and slag inclusion (Jeffus, 2012; Jeffus & Bower, 2010b).

Understanding that welders need to be dexterous to weld correctly would make a researcher hypothesize that if a person has a high level of dexterity then the person would be able to weld and vice versa. Therefore, if a dexterity test that replicates the psychomotor skills necessary for welding were implemented in a training program, would it be able to accurately predict the future performance of the trainees?

Theoretical Framework

The theoretical framework that guided this study was Campbell, McCloy, Oppler, and Sager’s (1993) determinants of job performance components. To understand determinants of job performance, one must ask what performance is. Campbell et al. (1993) stated that “performance consists of goal-relevant actions that are under the control of the individual, regardless of whether they are cognitive, motor, psychomotor, or interpersonal” (p. 40). In an industry setting confusion between performance, effectiveness, and productivity is common (Campbell et al., 1993). Therefore, an individual must understand the differences between the terms in order to fully comprehend what performance truly represents. Performance of a job will produce a result, whereas effectiveness is the systematic evaluation of the results of a performance (Campbell, 1999, Campbell et al., 1993). Productivity refers to the financial side, which studies how much money and effectiveness is needed to achieve the next level of effectiveness (Campbell, 1999, Campbell et al., 1993).

A Performance component is comprised of determinants and antecedents (Campbell et al., 1993). Refer to Figure 1. Performance components are categories of actions people are expected to complete as part of a job (Campbell, 1999, Campbell et al., 1993). Performance determinants include declarative knowledge; procedural knowledge and skill; and motivation (Campbell, 1999, Campbell et al., 1993). Differences between people that perform the same job are expressed through performance determinants. The three performance determinants compose a performance component (Campbell, 1999, Campbell et al., 1993). Declarative knowledge refers to the knowledge about facts and principals related to the job that an individual possesses (Campbell, 1999, Campbell et al., 1993). Procedural knowledge and skill is the combination of knowing what to do, declarative knowledge, with the skill to do it (Campbell, 1999, Campbell et al., 1993). Skills that fall under procedural knowledge include cognitive, psychomotor, physical, self-management, and interpersonal (Campbell, 1999, Campbell et al., 1993). The last determinant is motivation, which refers to the effort a person puts towards a job (Campbell, 1999, Campbell et al., 1993). This involves an individual making the decision to expend effort, determine what level of effort to exert, and how long to exert effort when performing a job (Campbell, 1999, Campbell et al., 1993).
Antecedents of performance determinants are the predictors of performance (Campbell, 1999, Campbell et al., 1993). Performance indicators of declarative knowledge include ability, personality, interests, education, training, experience, and aptitude interactions (Campbell, 1999, Campbell et al., 1993). Procedural knowledge and skill performance predictors consist of ability, personality, interests, education, training, practice, and aptitude interactions (Campbell, 1999, Campbell et al., 1993). Motivational antecedents are comprised of variables related to the theory of motivation being utilized (Campbell, 1999, Campbell et al., 1993). For this study, the researchers will focus on the performance antecedents of procedural knowledge and skill. The specific antecedent that will be examined is psychomotor skill as it relates to welding performance.
Purpose and Objectives

The purpose of this study was to examine if dexterity could predict the future performance of a beginning welder entering a welding training program. In addition, the study sought to describe the change in dexterity during the welding training program. This study also intended to determine if a relationship exists between an individual’s dexterity and pass/fail rating from the visual inspection of the test weld. This research aligns with the American Association for Agricultural Education’s National Research Agenda Priority Area 3: Sufficient scientific and professional workforce that addresses the challenges of the 21st century (Doerfert, 2011, p. 9). Specifically relating to improve agricultural productivity efficiency and effectiveness to increase sustainable growth in the private setting (Doerfert, 2011). The following objectives were identified to address the purposes of this study.

1. Describe the dexterity of the participants in a welding training program.
2. Report the pass/fail rating of visual inspection of test welds performed by participants.
3. Determine if a relationship exists between participant dexterity and the pass/fail rating of visual inspection of test welds.

Methods

This study is part of a larger research study that examined the effectiveness of integrated virtual reality welding training programs utilizing the VRTEX® 360 and VRTEX® Mobile units. This study was conducted at the Iowa State University where a virtual reality and real-world welding training laboratory were utilized. The individuals who participated in this study did so voluntarily. There were incentives for participation that included having lunch provided each day and having the weld certification test fees paid for. There were three female and 20 male participants within this study. The background of the participants varied between college students, secondary educators, to industry workers. The welding training programs were offered in five variations. Two programs utilized only the VRTEX® Mobile unit in a 100 percent virtual reality training and 50/50 virtual/traditional integrated training program. The programs that utilized the VRTEX® Mobile unit were only one week long. Three programs were offered as either 50/50 virtual/traditional, 75/25 virtual/traditional, and 100 percent virtual training utilizing the VRTEX® 360. The programs that utilized the VRTEX® 360 were two weeks long. The variation of training programs are based on the programs used in the study conducted by Stone, McLaurin, Zhong, and Watts (2013). In the study conducted by Stone et al. (2013) the program groups utilized was 50/50 virtual/traditional and 100 percent virtual reality training. The 75/25 virtual/traditional group was added to determine if

To obtain dexterity data about the participants the researchers utilized the Complete Minnesota Dexterity Test (CMDT). The CMDT is used to measure a person’s rapid eye-hand coordination and arm-hand dexterity also known as gross motor skills (Lafayette Instrument, 2012). This test consists of five parts, but only three were utilized because they closely replicated the movements used during the welding process. The tests that were completed by the participants included: a) placing test; b) turning test; and c) displacement test. The CMDT utilizes two test boards, each containing 60 holes. Sixty corresponding disks are utilized during the tests that participants manipulated with their hands and arms. The participants were required to stand for the dexterity tests. The dexterity tests were completed by participants on the first day of the welding training
program and after the test welds were completed on test days. Depending on which training
program the participants were in determined how many times the dexterity tests were completed. Participants in the one-week session completed dexterity tests twice. During the two-week long
session, participants completed the dexterity tests three times.

In the placing test, the two boards are laid on a tabletop side by side about 1” from the edge of
the table. The board farthest away will have the disks in it. When the examiner says start, the
participant using their dominant hand will move the disks one by one from the top board to the
bottom board. The participant’s non-dominant hand must not be used to brace the participant in
anyway during the test. Once all the disks have been placed the time taken to complete the test
was recorded.

The turning test used only one board and all 60 disks. Starting in the top right corner, the
participant used one hand to pick up a single disk, turn it with the other hand, and then place it
back in the board. The participant will replicate this for all discs on the top row of the board,
then go to the next row below and go back across the board. They will follow this procedure
until all of the disks have been turned, and the amount of time needed to complete the test was
recorded.

The displacement test also used one board and all 60 disks. With all the disks inserted into the
board, the participant will be instructed to remove the disk from the top left hand corner of the
board and place it to the side. This test will require the participant to move the disk directly
below the empty space up into it. Then following the same procedure until the participant has
went all the way across the board. Time was recorded once the participant has completed the
test.

For each test, the participants were given a practice run to fully understand how to perform the
tests. Following the practice run, the participants completed the test three times. The time for
the practice run and all three test runs were recorded. The three test times were then averaged.
The average was used along with the interpretation chart developed by Ziegler, Jurgensen,
Harmon, Roberts, and Bauman (American Guidance Service, 1969), included with the test to
find the participants percentile rank. The percentile scale is used to interpret a subject’s score in
terms of percent of the normative population, the scale ranged from zero to 100 (Lafayette

After all the participants completed the welding training programs they were given the
opportunity to complete test welds that were visually inspected by a certified welding inspector
(CWI). The length of the training program dictated how many test welds were to be completed
by the participants. The four possible test welds a participant could perform were 2F (horizontal
fillet weld), 1G (flat groove weld), 3F (vertical fillet weld), and 3G (vertical groove weld). The
participants performed the welds utilizing shielded metal arc welding (SMAW) and gas metal arc
welding (GMAW) processes. The participants in the one-week session completed the 2F and 1G
welds for both welding processes. Whereas the two-week session participants completed all four
weld types in both welding processes. The CWI examined the test weldment and measured for
the following discontinuities underfill, overfill, undercut, porosity, lack of fusion, and cracks
according to AWS D1.1 structural welding code. The data from the visual inspection was
recorded as pass or fail.
The data were analyzed using Microsoft Excel 2010 and Predictive Analytics SoftWare (PASW) Statistics 18 software package. Descriptive statistics were calculated to identify frequencies for pass/fail rates and dexterity percentile rankings. A bivariate correlation was calculated to examine the relationship between recorded times and visual pass/fail rates. With a numerical variable and a dichotomous variable utilizing the bivariate correlation calculation was needed to evaluate the relationship between the variables (Gravetter & Wallnau, 2009). Researchers utilized the r squared (r2) statistic to examine the effect size of the bivariate correlation. To evaluate the effect size of a bivariate correlation Gravetter and Wallnau (2009) indicated that r2 should be used.

Results

The performance measures used in this study included the time it took to complete the dexterity tests and the visual inspection of participants test welds. Objective one sought to describe the average dexterity of the participants of this study. Table 1 shows the average dexterity in quartiles of the population norm. For example, if you put the entire population on a scale of zero to 100, the quartiles would be 25 (low), 50 (medium), 75 (high), and 100 (very high). Dexterous ability was lowest at zero and is highest at 100. This means that the participants in the 25 percent quartile represent those with the least dexterous ability. The individuals in the 100 percent quartile represent those with the most dexterous ability within the population.

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>25% f (%)</th>
<th>50% f (%)</th>
<th>75% f (%)</th>
<th>100% f (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Day of Traininga</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placing</td>
<td>18(78.3)</td>
<td>3(13.0)</td>
<td>2(8.7)</td>
<td>0(0.0)</td>
</tr>
<tr>
<td>Turning</td>
<td>18(78.3)</td>
<td>3(13.0)</td>
<td>1(4.3)</td>
<td>1(4.3)</td>
</tr>
<tr>
<td>Displacement</td>
<td>9(39.1)</td>
<td>5(21.7)</td>
<td>1(4.3)</td>
<td>8(34.8)</td>
</tr>
<tr>
<td>Week 1 Test Daya</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placing</td>
<td>11(47.8)</td>
<td>4(17.4)</td>
<td>3(13.0)</td>
<td>5(21.7)</td>
</tr>
<tr>
<td>Turning</td>
<td>13(56.5)</td>
<td>2(8.7)</td>
<td>0(0.0)</td>
<td>8(34.8)</td>
</tr>
<tr>
<td>Displacement</td>
<td>9(39.1)</td>
<td>1(4.3)</td>
<td>2(8.7)</td>
<td>11(47.8)</td>
</tr>
<tr>
<td>Week 2 Test Dayb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placing</td>
<td>7(46.7)</td>
<td>0(0.0)</td>
<td>0(0.0)</td>
<td>8(53.3)</td>
</tr>
<tr>
<td>Turning</td>
<td>6(40.0)</td>
<td>0(0.0)</td>
<td>2(13.3)</td>
<td>7(46.7)</td>
</tr>
<tr>
<td>Displacement</td>
<td>3(20.0)</td>
<td>2(13.3)</td>
<td>0(0.0)</td>
<td>10(66.7)</td>
</tr>
</tbody>
</table>

*Note. a n = 23, b n = 15.*

When examining participant dexterity on the first day of training, it can be identified that with the placing and turning tests 78.3 percent of the participants had low dexterous ability. However, 34.8 percent of participants exuded a very high level of dexterity on the displacement test the first day of training. An increase in dexterous ability can be seen from the first day of training to the test day of week one. This is evident with the placing test where the first day of training shown none of the participants were identified as having very high dexterity, but after the week
one test day 21.7 percent (n = 5) of the participants had a very high dexterous ability. This increase in dexterous ability was also evident in the turning and displacement tests. The increase of dexterous ability continued on the week two test day. The number of participants exuding a very high level of dexterity grew by 11.9 – 31.6 percent.

To further examine this increase in dexterous ability, the data were separated by the type of training program. The participants in the 50/50 virtual/traditional training program, had no change in dexterous ability from the first day of training to the week one test day. However, in the 100 percent virtual training program a growth in dexterous ability can be seen in all three types of tests. Although, the displacement test shown 25 percent of participants dropped in their dexterous ability in the one-week training program.

Participant dexterity for the two-week training programs has been separated. In the 50/50 virtual and traditional training method, an overall increase in dexterous ability can be seen across all three types of tests completed. The one exception was on week two-test day where 13.7 percent of participants fell from the 50 percent group to the 25 percent group. The drop indicates a loss of dexterous ability. The 75/25 virtual/traditional training group shown an increase in overall dexterous ability for all types of tests completed on test days for both weeks. The most striking change is in the turning test, where 80 percent of the participants had an increase in dexterity. Within the 100 percent virtual training group, participants also had an overall increase in dexterity. The placing and turning tests had the highest increase in ability where 75 percent of participants had a positive shift in ability.

Objective two examined the visual inspection, based on AWS D1.1 standards, of participants’ test welds. The rating of the visual inspection was either a pass or fail, determined by a CWI. It can be determined that the participants fared better with the groove welds than the fillet welds in both weld processes. This is shown in the overall pass/fail rates as the groove welds are the only weld type that has a majority of participants passing visual inspection in both weld processes. The weld type that had the highest number visual inspections that passed was the 1G in each weld processes. The most difficult weld for the participants of this study was the 3F in both weld processes.

If we examine the pass/fail rate by training program type several patterns can be identified. In the 50/50 virtual/traditional one-week program, the majority of the participants failed visual inspection in all weld types except the 1G in the GMAW welding process. Within the 100 percent virtual one-week training program a majority of participants passed visual inspection, expect in the GMAW 2F weld. When examining the two-week training programs, the 50/50 virtual to traditional group failed 60 percent (n = 29) of test weld visual inspections. However, the 75/25 virtual/traditional group passed 62.5 percent (n = 25) of visual inspections. The 100 percent virtual group failed 59 percent (n = 19) of the test weld visual inspections.

The third objective of this study sought to examine the relationship between participant dexterity and the participants corresponding visual inspection pass/fail rates. To examine the relationship a bivariate Pearson’s correlation was calculated. The results can be seen in Table 2. All three dexterity tests given were found to be significant with the visual pass/fail rates of the participants for the 2F and 1G weld types in the SMAW welding process. The placing test was found to be significant with the 2F weld type on the first day of training. However, all three dexterity tests
were found significant with the 2F weld type on test day of week one. The turning test was significant with the 2F weld type on test day of week two. The 1G weld type found significance on both test days with the turning test only.

Table 2
Bivariate Correlations between Participant Dexterity and Visual Inspection Pass/Fail Rate

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>SMAW</th>
<th>GMAW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2F r(p)</td>
<td>1G r(p)</td>
</tr>
<tr>
<td>1st Day of Training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placing</td>
<td>.417* (.048)</td>
<td>.257 (.237)</td>
</tr>
<tr>
<td>Turning</td>
<td>.117 (.596)</td>
<td>.351 (.100)</td>
</tr>
<tr>
<td>Displacement</td>
<td>.206 (.345)</td>
<td>.244 (.262)</td>
</tr>
<tr>
<td>Week 1 Test Day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placing</td>
<td>.590** (.003)</td>
<td>.351 (.101)</td>
</tr>
<tr>
<td>Turning</td>
<td>.614* (.002)</td>
<td>.546** (.007)</td>
</tr>
<tr>
<td>Displacement</td>
<td>.619* (.002)</td>
<td>.406 (.055)</td>
</tr>
<tr>
<td>Week 2 Test Day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placing</td>
<td>.428 (.111)</td>
<td>.066 (.815)</td>
</tr>
<tr>
<td>Turning</td>
<td>.642** (.010)</td>
<td>.560* (.030)</td>
</tr>
<tr>
<td>Displacement</td>
<td>.450 (.092)</td>
<td>.140 (.620)</td>
</tr>
</tbody>
</table>

Note. *p = 0.05, **p = 0.01.

To interpret the magnitude of the relationship between two variables, Gravetter and Wallnau (2009) indicated that r2 should be used. The results of the r2 calculations can be seen in Table 4.6. Gravetter and Wallnau (2009) suggested the following scale when interpreting the r2 statistic: 0.01 = small effect; 0.09 = medium effect; 0.25 = large effect. Following the suggestions of Gravetter and Wallnau (2009), all the dexterity tests exhibited a very large effect on the pass/fail rates of the participants test welds. The turning test exhibited the largest effect in the study on test day of week two. The placing test on the first day of training exhibited a large effect on the pass/fail rate, yet was the lowest out of the tests that revealed a significant relationship.
Table 3

<table>
<thead>
<tr>
<th>Dexterity Test</th>
<th>N</th>
<th>r</th>
<th>p</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2F-SMAW</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placing Test (0)</td>
<td>23</td>
<td>.417</td>
<td>.048*</td>
<td>.173</td>
</tr>
<tr>
<td>Placing Test (1)</td>
<td>23</td>
<td>.590</td>
<td>.003**</td>
<td>.348</td>
</tr>
<tr>
<td>Turning Test (1)</td>
<td>23</td>
<td>.614</td>
<td>.002**</td>
<td>.377</td>
</tr>
<tr>
<td>Displacement Test (1)</td>
<td>23</td>
<td>.619</td>
<td>.002**</td>
<td>.383</td>
</tr>
<tr>
<td>Turning Test (2)</td>
<td>15</td>
<td>.642</td>
<td>.010**</td>
<td>.412</td>
</tr>
<tr>
<td><strong>1G-SMAW</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turning Test (1)</td>
<td>23</td>
<td>.546</td>
<td>.007**</td>
<td>.298</td>
</tr>
<tr>
<td>Turning Test (2)</td>
<td>15</td>
<td>.560</td>
<td>.030*</td>
<td>.313</td>
</tr>
</tbody>
</table>

*Note.* *p* = 0.05, **p = 0.01.

Conclusions and Discussion

From the results of this study several conclusions can be drawn. First, one trend that was identified was dexterous ability for a majority of the participants increased during the training program. Conversely, there were several participants that either exhibited no change in dexterous ability or they lost dexterity during the training program. The change in ability supports the notion that it takes time to master the craft of welding (Giachino & Weeks, 1985). Because of the increase in dexterous ability over the first week of training raises the question would it be better to test for dexterity after the first week of training? Do participants need a sufficient amount of time to become acclimated to the new skills they are learning before being tested or should a person’s innate ability before learning new skills be the basis of selection?

It can also be concluded that with more time in a virtual reality environment the larger the increase of dexterous ability. This is evident in all but the 50/50 virtual/traditional training methods. This suggests that the virtual reality gives participants the capability to hone task related abilities, which supports the conclusions of previous research using simulations in the medical, dental, and welding fields for training purposes (Boulet et al., 2003; Kunkler, 2006; Papadopoulos et al., 2013; Stone et al., 2011). With the VRTEX® systems users are able to get instant feedback through numerical grades and graphical representations of the welding parameters. The use of cheater lenses that help guide the user to the correct angles, speed, position, and arc length can also be used. With traditional training methods, it is a trial and error type of learning environment where there is no instant feedback given when you weld. The feedback in a traditional training program comes after showing an instructor. From the results, it can be concluded that dexterity can increase with the use of both instant and accurate feedback.

When examining the pass/fail rates from the visual inspections, it can be concluded that participants were better at performing the less complex welds. It can also be concluded that the 100 percent virtual training programs performed the 1G weld better than the other training programs. The 75/25 virtual/traditional training methods outperformed the other training method types. This suggests that the 75/25 virtual/traditional training method may best suited at preparing beginning welders. As virtual reality given the ability to replicate welds faster than
Objective three sought to explore the relationship between participant dexterity and the pass/fail rating of the visual inspection in order to examine the predictability of dexterity on future performance. This reinforces Campbell et al. (1993) determinants of job performance component procedural knowledge and skill because dexterity can affect overall task performance. It can be concluded that dexterity can predict future performance of beginning welders completing basic SMAW welds. The ability of dexterity to predict future performance supports the finding in other occupational fields (Gansky et al., 2004; Gettman et al., 2003; Hitchings & Moore, 1991; Levine et al., 1996; Mansell, 1969). All of the tests utilized shown a significant relationship with a beginning welder’s ability to visually pass/fail inspection by a CWI. This implies industry personnel can use dexterity to select people to enter welding training programs that use basic SMAW welds.

**Recommendations**

Conclusions from this study lead to several recommendations. First, it is recommended that welding training programs utilize virtual reality simulations to aid in the training process. With the use of virtual reality, welding training programs can become more efficient, in terms of passing visual inspections, which is imperative to meet today’s demand for certified welders. With the increased need for certified welders, it is a necessity to create efficient training programs.

With the ability to use dexterity to predict future performance with simple welds, it is recommended that training programs that teach simple welds use dexterity testing to select individuals to enter the training program. With the requisite of having high dexterity may lead to better candidate selection for the welding training programs. With the influx of individuals drawn to welding by virtual reality simulators, welding training programs will be able to objectively select the best individuals for training.

The researchers also recommend that future studies be conducted to further examine the use of dexterity to predict future performance by utilizing different dexterity tests. Further investigation is needed to examine if dexterity can predict future performance for more complex welds. It is suggested to use dexterity tests that evaluate fine, finger and hand, and gross, hand and arm, dexterity. It is also recommended that future studies look into the possibility of creating a dexterity test that more resembles the movements of a welder to improve the ability of dexterity to predict future performance. Further investigation is needed to determine if dexterity can predict future performance of GMAW type welds. Is GMAW easier to perform than SMAW type welds and is that why dexterity is not an indicator?

**References**


