The CTE Journal ISSN 2327-0160 (Online)
Volume 6. Number 1.

The Utilization of an Alternative Welding Consumable Management Strategy in a School-based Agricultural Mechanics Course: A Preliminary Quasi-Experimental Study

Alaina Imhoff

Mediapolis High School

imhoffa@mepoedu.org

Ryan Anderson

Sauk Valley Community College

ryan.g.anderson@svcc.edu

Abstract

Laboratory instruction remains prominent within school-based agricultural education programs (Phipps, Osborne, Dyer, & Ball, 2008), particularly in the realm of agricultural mechanics. Welding occupies a prominent content area within agricultural mechanics (Anderson, Velez, & Anderson, 2014). As such, consumable materials, such as welding electrodes, can occupy a significant expense within program budgets (Saucier, Vincent, & Anderson, 2014). Using a quasi-experimental design and guided by Ajzen's (1985) theory of planned behavior, this preliminary study examined the use of an alternative electrode management strategy and its effects on waste material production and cost to an agricultural education program. The results of the present study suggested that the use of the alternative micromanagement strategy resulted in minimal, negligible cost savings; however, the use of the micromanagement strategy did decrease the quantity of electrode waste. Perhaps agricultural education teachers should instead focus upon intensive micromanagement of consumable metals used during welding activities. The researchers suggest that agricultural education teachers should, in order to decrease consumable electrode costs, work to purchase electrodes directly from manufacturers instead of through welding supply distributors. The researchers recommend that this study be replicated in additional agricultural education programs. Replication efforts should develop and utilize a true experimental design.

Introduction

Laboratory instruction remains a prominent teaching arena within school-based agricultural education (SBAE) programs (Phipps, Osborne, Dyer, & Ball, 2008; Shoulders & Myers, 2012). Within laboratory settings, students are granted opportunities to engage in critical thinking to solve problems, psychomotor skill development to enhance technical performance, and project-based learning to apply newly-learned skills and thinking to a physical apparatus (Phipps et al., 2008; Shoulders & Myers, 2012; Wells, Perry, Anderson, Shultz, & Paulsen, 2013). A wide variety of teaching environments are used within SBAE, including greenhouses, livestock facilities, and agricultural mechanics laboratories (Phipps et al., 2008; Shoulders & Myers, 2012). Perhaps one of the most common laboratory facility, agricultural mechanics facilities are in a substantial number of SBAE programs across the United States (Burris, Robinson, & Terry, 2005; Shoulders & Myers, 2012; Shultz, Anderson, Shultz, & Paulsen, 2014; Wells et al., 2013).

Within agricultural mechanics laboratories, a variety of content is addressed that ranges from electricity, welding and metal fabrication, and carpentry, to plumbing, power machinery repair, and soil and water conservation (McCubbins, Anderson, Paulsen, & Wells, 2016; Shultz et al., 2014; Wells et al., 2013). This broad expansion and diversity of content is designed to allow for a considerable breadth of skills-based education that can be useful to a broad audience of students (Phipps et al., 2008). Further, this expansive list also provides a multitude of opportunities for career area exposure for students, ultimately broadening their horizons and expanding their thinking about future possibilities (Phipps et al., 2008). One such agricultural mechanics content area that has remained popular for both agricultural education teachers and students is welding (Anderson, Velez, & Anderson, 2014; Burris et al., 2005). As many programs include welding instruction as a considerable portion of the delivered content (Anderson et al., 2014; McCubbins et al., 2016), teachers must pay special attention to the role that the content area plays within SBAE programs, including budgetary decisions, equipment and facilities management, and student interests and engagement during instructional sessions (Phipps et al., 2008).

As described by Herren (2015), welding is the process by which heat is used to melt and join two individual pieces of metal together into one whole piece. This process is accomplished by using a welding machine that converts electrical energy into heat energy to melt metal at a specific location. The most common welding processes utilize an electrode that varies by process type, and can range from “[flux-] coated metal rods” (Herren, 2015, p. 389) to copper wire to tungsten, depending upon the welding process being used. Regarding welding processes, shielded metal arc welding (SMAW), gas metal arc welding (GMAW), gas tungsten arc welding (GTAW), and flux-cored arc welding (FCAW) are most often taught within agricultural mechanics laboratories in SBAE, with each process requiring specific equipment and materials necessary to complete its designated welding task (Herren, 2015). These significant differences between each welding process influence and dictate the actions that occur during each. For example, the SMAW process utilizes a flux-coated rod that serves as the consumable electrode, which burns and decreases in quantity available during the welding process, while the GTAW process uses a non-consumable tungsten electrode that can be used repeatedly, so long as the electrode is maintained and kept clean (Herren, 2015). The differences between welding process types and the equipment needed (i.e., electrodes and other consumables) to successfully perform each process have influence over the initial inputs, such as budgetary concerns, related to the teaching and learning of welding content within SBAE program settings. For the purposes of the present study, the researchers have selected to focus on the SMAW process.

Cost Considerations for Laboratory-based Welding Instruction

Available funding and budgets for agricultural mechanics laboratories can hold influence over the content taught, tools, equipment, and work materials available for use, as well as the utility of the laboratory facility itself (McKim & Saucier, 2013; Saucier, Vincent, & Anderson, 2014). As such, each of these factors can contribute significantly to the overall structure of agricultural mechanics education within SBAE programs (Saucier et al., 2014). As part of these financial considerations related to teaching materials, the overuse of consumables can devour a significant portion of program budgets if left unchecked (Saucier et al., 2014). Consumables used within agricultural mechanics laboratories are often costly (McKim & Saucier, 2013); thus, their efficient use is requisite. In terms of agricultural mechanics instruction, consumables within a welding unit can include welding gases, welding wire, filler rods, metal, and, in the scope of the present study, welding electrodes (Herren, 2015).

Recent research (McKim & Saucier, 2013; McKim & Saucier, 2012) has helped to describe the scope of laboratory management competencies of agricultural mechanics teachers. Interestingly, McKim and Saucier (2013) found that agricultural mechanics teachers' "…average [consumables] budget increased between 1989 and 2008, by nearly $500" (p. 162), to an average total of $2,900. However, this overall budget increase did not keep pace with inflation over the same period of time. As also noted by McKim and Saucier (2013), "…the average agricultural mechanics consumable supply budget would have needed to increase to $4,349… to account for inflation alone" (p. 162). This inadequate increase in available funding can result in quite the challenge for agricultural mechanics instruction, quite possibly limiting prospective projects, content areas, and other means of teaching (Saucier et al., 2014). As the consumable supplies for teaching welding content are quite expansive and can include specialized tools and equipment (e.g., welding machines, wire brushes, etc.), metal for student practice plates and projects, safety equipment, as well as welding electrodes, these items and their effective and efficient usage must be factored into laboratory management and instructional planning.

Besides metal, electrodes remain the most largely used and expensive consumable item used within the process of teaching and learning of welding skills (The ESAB Group, 2000). Thus, the wide and efficient use of welding electrodes is vital in proper agricultural mechanics laboratory budget management. Regarding the efficiency of welding electrode usage, the welding industry has given considerable effort to minimizing consumable material loss (The ESAB Group, 2000). As the purpose of welding is the melting and joining of metals through the use of a heat-transferring electrode (Herren, 2015), filler metal within the electrode is deposited to help form and complete the weld (The ESAB Group, 2000). Thus, deposition efficiency remains a factor in electrode usage and management. Deposition efficiency is calculated based on the total weight of the weld metal deposited during the welding process divided by the weight of the electrode that was consumed during the welding process (The ESAB Group, 2000). This formula, as defined by The ESAB Group (2000) can be expressed as:

$$\text{Deposition efficiency} = \frac{\text{Weight of weld metal}}{\text{Weight of electrode consumed}}$$

Understanding deposition efficiency, which does vary between electrode types and sizes (The ESAB Group, 2000), allows for a greater understanding of the consumption of welding electrodes and, as a result, welding consumables management. Any unnecessary loss of welding electrode can result in decreased efficiency of consumables usage, and thereby increase the costs associated with welding (The ESAB Group, 2000). Regarding this efficiency, the formula described by The ESAB Group (2000) and given below provides a method of mathematical calculation of welding electrode efficiency.

$$\text{Efficiency minus stub loss} = \frac{(\text{Electrode length} - \text{Stub length remaining}) \times \text{Deposition efficiency}}{\text{Electrode length}}$$

These factors ultimately provide great contribution to the costs associated with providing consumable materials (i.e., electrodes) for laboratory instruction in welding. As such, laboratory instruction quantity and quality can be greatly influenced by the resources available (McCubbins et al., 2016; McKim & Saucier, 2013). These resources, while including tools and equipment, certainly encompass consumable welding electrodes that, ultimately, are used by students during the welding process (Herren, 2015). However, in addition to the concepts given previously (i.e., deposition efficiency, etc.), the human capital factor (e.g., students enrolled in agricultural mechanics coursework) must be accounted for. Moreover, as secondary students have often had little welding exposure prior to agricultural mechanics courses, it could be expected that this particular group would consume a greater amount of welding electrodes than older, more experienced welders. In seeking to determine more efficient agricultural mechanics laboratory budget administration, the researchers explored the possibility of implementing an alternative method of welding consumables management.

Theoretical Framework

To frame and guide the present study, the researchers utilized Ajzen's (1985) theory of planned behavior. Per Madden, Ellen, and Ajzen (1992), "[t]he theory of planned behavior (Ajzen, 1985) extends the boundary condition of pure volitional control… by including beliefs regarding the possession of requisite resources and opportunities for performing a given behavior" (p. 4). Further, this theory was selected based upon the notion of using an alternative management strategy to monitor students' use and consumption of consumable welding electrodes. A modified version of this theory is presented in Figure 1 below.

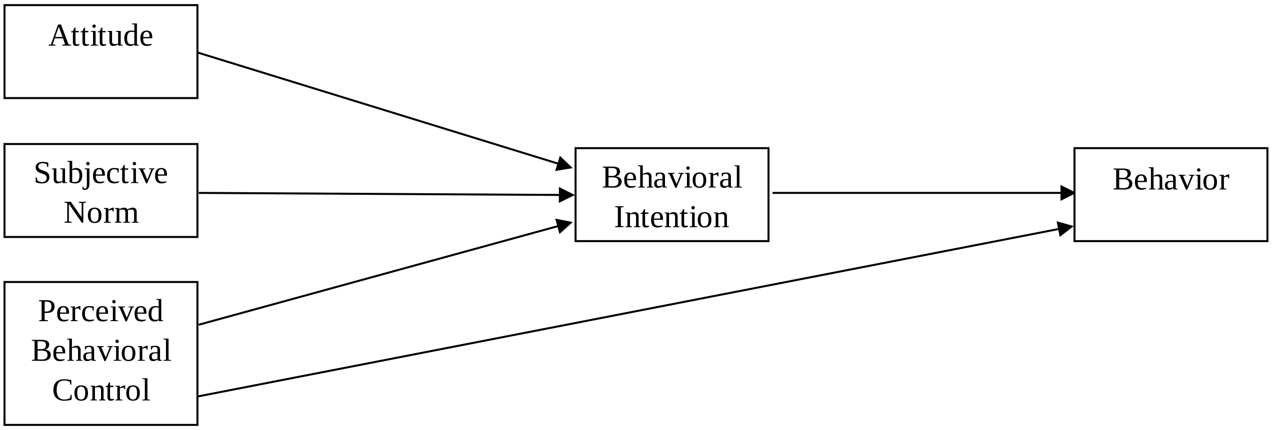

Figure 1. Modified version Ajzen's (1985) theory of planned behavior.

Regarding the utilization of this particular theory for the present study, the factors that were most focused upon were *Perceived Behavioral Control* and *Behavior*. As operationalized within the present study, *Perceived Behavioral Control* was described as the use of an alternative welding consumable management strategy to help control students' consumption of welding consumables (i.e., electrodes). *Behavior* was classified as students' performance of welding-related actions; in this instance, the output amounts (e.g., spent electrode waste) from actual use of electrodes during the welding process was the most specific item to be measured. However, the other factors of *Attitude*, *Subjective Norm*, and *Behavioral Intention* were also taken into consideration. *Attitude* was defined as the attitudes that the students within the present study had toward the welding process and their roles within it. *Subjective Norm* described students' perceptions of socially-based influences and pressures from their fellow students and their agricultural education teacher to engage in the course, its content, and activities associated with welding, while *Behavioral Intention* was regarded as motivation and perseverance to perform and follow through with the welding activities selected for the course. As each of these variables interact to produce some form of an outcome behavior, these elements, though not the primary focus of the present study, were still adequately defined and prepared for use.

Research Question, Purpose, & Objectives of the Study

Based upon Ajzen's (1985) theory of planned behavior, the primary research question that guided the present study was: What effects, if any, would the use of an alternative welding consumable management strategy have on students' consumption of welding electrodes within a school-based agricultural mechanics setting? As such, the purpose of this study was to describe the effects that the use of an alternative welding consumable management strategy would have on students' consumption of welding electrodes. To address both the research question and this purpose, the researchers developed the following objectives:

> 1) Determine students' welding consumables usage when employing differing consumables management strategies.
>
> 2) Evaluate the cost-effectiveness of limiting students' access to using consumable welding electrodes.

Methods

The present study was conducted during the 2015-2016 academic year within a section of the Agriculture III welding course at [SCHOOL] in [STATE], which had an enrollment of eight students (*N* = 8). Regarding the student participants, all were junior- and senior-level students who ranged in age from 16 to 18 and had little prior welding experience. Three of the student participants were female (*n* = 3), while five were male (*n* = 5). At the beginning of the course, all students were given a course syllabus that detailed the activities and expectations within the curriculum, including details regarding the present study. The students were also informed that while class grades were to be assigned based on participation and successful completion of course welding activities, their performance in the present study (i.e., consumable electrode use) would not affect their grades at all.

This design for the present study was quasi-experimental in nature. Per Ary, Jacobs, and Sorensen (2010), quasi-experimental studies allow for quality research to be conducted when randomization of subjects cannot reasonably occur, such as within a school-based setting. Regarding the implementation of the study, the welding training experience was conducted over a period of 13 80-minute course meetings. Data were collected only during 10 course meetings that addressed welding. The agricultural education teacher, per the design of the study, dictated which part of the experimental process the students were participating in. The welding consumables management strategy varied by day, whereas on odd-numbered days, students were micromanaged and were not granted access to additional welding electrodes until each had less than two inches of its original length remaining. Otherwise, during even-numbered days, students were granted an unlimited allowance of welding electrodes. To provide clarity as to how the two inch length was determined, Figure Two depicts the use and deposition of a welding electrode during the welding process.

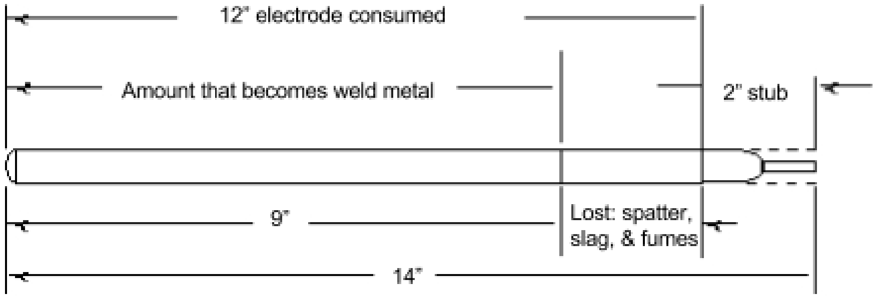

Figure 2. Welding electrode use and deposition. Reprinted from The ESAB Group (2000).

During the first three of the thirteen welding content-related course meetings, the agricultural education teacher covered a variety of topics pertinent to the welding content within the course. These topics included welding terminology, safety and personal protective equipment, welding machine set-up and use, metal types, welding positions and joint types, welding techniques and dexterity, and welding tools and equipment (i.e., bench grinders, etc.) and their usages. Students were also allocated time to practice using the welders and welding tools and equipment during the third course meeting.

Throughout the following 10 days, the experimental procedures of the study were implemented. During this time, all students had access to mild steel welding coupons that measured approximately one-eighth inch thick, three inches wide, and four inches long. The electrodes used in the present study were either E6011 or E6013, measured one-eighth inch in diameter and 14 inches long, were manufactured by the same electrode supplier, and were acquired at the same time to help provide congruency between the different electrodes. On the first of the 10 days, students were granted unlimited access to the welding electrodes and were assigned to work, in pairs, to develop their welding dexterity competencies, such as proper arc length, travel speed, travel angle, and work angle. Students also worked to practice creating and laying welding beads using different movement and patterning techniques that had previously been discussed during the prior three days.

During the welding activities, the agricultural education teacher observed students, critiqued welding techniques, and gave feedback to help facilitate skill development and growth. During clean-up activities at the end of this course meeting, students were instructed to place any spent welding electrode waste into a specially-marked and dated container. It should be noted that at the conclusion of each day during the study, the container of electrode waste material corresponding to that particular day was weighed using a triple beam balance. The triple beam balance was checked for accuracy and calibrated each day before use. Because the triple beam balance provided measurements in grams, these measurements were converted to ounces. This technique was repeated for the entire duration of the study.

On the second of the 10 days, students were once again assigned to work in pairs during the day's activities. In contrast to the day prior, students were not allowed to use welding electrodes at their convenience. Instead, students were only granted a new welding electrode when the current electrode had only two inches or less in length remaining, as determined by the agricultural education teacher. As during the first day of the experiment, the agricultural education teacher observed students, critiqued welding techniques, and gave feedback directly to the students. During clean-up activities at the end of this course meeting, students were instructed to place any spent welding electrode waste into a specially-marked and dated container, congruent with procedures conducted during the prior course meeting.

During the third of the 10 days, students were instructed to work solo during the day's welding activities, which continued throughout the remainder of the study's allotted duration. Mimicking the procedures of the first day of the experiment, students had unlimited access to electrodes and coupons. Students were assigned to practice horizontal butt joint welds and were observed and provided critiquing and feedback by the agricultural education teacher. As during prior course meetings, students were instructed to place any spent welding electrode waste into a specially-marked and dated container during clean-up activities. On the fourth of the 10 experimental days, students once again worked solo to practice and compete horizontal butt joint welds and were observed and provided critiquing and feedback by the agricultural education teacher; however, as on the second day students were only granted a new welding electrode when the current electrode had only two inches or less in length remaining, as determined by the course teacher. As during prior course meetings, students were instructed to place any spent welding electrode waste into a specially-marked and dated container during clean-up activities.

Days five, seven, and nine (all odd-numbered days) continued under the same structure set forth in day three, while days six, eight, and ten (all even-numbered days) operated under the same procedures used in day four. However, the exception to this pattern was the students attempted more difficult welds during each successive course meetings. During the clean-up phase of each course meeting, students, as described previously, placed any spent welding electrode waste into specially-marked and dated containers. As depicted below, Table 1 details the course meeting number, primary activity conducted during each meeting, and the consumable electrode management strategy used during each course meeting.

Table 1.

Course Meeting Number, Primary Activity, and Consumable Management Strategy Utilization

Meeting / Study Day Number	Primary Activity	Consumable Electrode Management Strategy Used
1 / -	Introduction to welding, welding safety	-
2 / -	Safety test, dexterity practice activity	-
3 / -	Welding machine set-up, welding practice	-
4 / 1	Students worked in pairs; welding practice	Unlimited access
5 / 2	Students worked in pairs; welding practice	Limited access
6 / 3	Students worked solo; welding practice	Unlimited access
7 / 4	Students worked solo; welding practice	Limited access
8 / 5	Students worked solo; welding practice	Unlimited access
9 / 6	Students worked solo; welding practice	Limited access
10 / 7	Students worked solo; welding practice	Unlimited access
11 / 8	Students worked solo; welding practice	Limited access
12 / 9	Students worked solo; welding practice	Unlimited access
13 / 10	Students worked solo; welding practice	Limited access

Note: Unlimited access – students were not restricted in their use of electrodes;
Limited access – students could only use an additional electrode if the remainder of the prior electrode was less than two inches.

Results

Table 2 displays the lengths of the electrodes that were used during each day of the study. Study day number, the number of students participating, the total number of electrodes used, the shortest and longest electrodes measured at the conclusion of each day's welding activities, the average length of all measured electrodes used, and the consumable electrode management strategy employed each day are detailed below.

Table 2.

Electrode Lengths Recorded Per Day of Study (Measured to Nearest 1/32”)

Study Day Number	Number of Students Participating	Total Number of Electrodes Used	Shortest Electrode Measured	Longest Electrode Measured	Average Length of All Measured Electrodes	Consumable Electrode Management Strategy Used
1	8	9	1 $^{3/32}$”	13 $^{1/8}$”	5 $^{3/8}$”	Unlimited
2	7	16	3/4”	3 $^{1/4}$”	1 $^{5/8}$”	Limited
3	7	11	3/4”	13 $^{3/4}$”	2 $^{5/8}$”	Unlimited
4	8	23	13/32”	2 $^{3/16}$”	1 $^{1/16}$”	Limited
5	8	11	9/16”	10 $^{5/32}$”	2 $^{5/32}$”	Unlimited
6	8	9	3/4”	4 $^{1/16}$”	1 $^{13/16}$”	Limited
7	5	17	7/16”	2 $^{9/32}$”	1 $^{3/16}$”	Unlimited
8	6	15	9/16”	2 $^{15/32}$”	1 $^{3/32}$”	Limited
9	7	16	3/8”	1 $^{15/16}$”	1 $^{3/16}$”	Unlimited
10	6	17	1/2”	7 $^{7/8}$”	1 $^{19/32}$”	Limited

Note: Unlimited – students were not restricted in their use of electrodes; Limited – students could only use an additional electrode if the remainder of the prior electrode was less than two inches.

Data from Table 3 provide a comparison of electrode use between consumable electrode management types (e.g., unlimited access or limited access). Per the design of the study, all electrode waste was measured and totaled at the conclusion of the study.

Table 3.

Comparison of Electrode Waste between Consumable Electrode Management Strategy Types (Measured to Nearest 1/32”)

	Consumable electrode management strategy used	
	Unlimited access	Limited access
Total length of all electrodes:	140 $^{23/32}$”	108 $^{21/32}$”
Total number of electrodes used:	64	79
Average length of all measured electrodes:	2 $^{3/16}$”	1 $^{3/8}$”

Note: Unlimited access – students were not restricted in their use of electrodes;

Limited access – students could only use an additional electrode if the remainder of the prior electrode was less than two inches.

Table 4 details the total weight of all electrode waste material generated during each day of the study. Using a triple beam balance, electrode materials were weighed at the conclusion of each day of the study.

Table 4.

Weight of Electrode Waste Material Collected Per Day of Study

Study Day Number	Number of Students Participating	Total Number of Electrodes Used	Weight of Electrode Waste Material (In Ounces)	Consumable Electrode Management Strategy Used
1	8	9	2.99	Unlimited access
2	7	16	1.62	Limited access
3	7	11	1.80	Unlimited access
4	8	23	1.55	Limited access
5	8	11	1.38	Unlimited access
6	8	9	0.95	Limited access
7	5	17	1.38	Unlimited access
8	6	15	1.06	Limited access
9	7	16	1.34	Unlimited access
10	6	17	1.73	Limited access

Note: Unlimited access – students were not restricted in their use of electrodes;
Limited access – students could only use an additional electrode if the remainder of the prior electrode was less than two inches.

Data from Table 5 detail a cost comparison between differing consumable electrode management strategies as well as electrode purchasing sources. These sources included purchasing from a welding supply distributor as well as purchasing directly from an electrode manufacturer.

Table 5.

Cost Comparison between Differing Consumable Electrode Management Strategies and Electrode Purchasing Sources

Consumable Electrode Management Strategy Used	Total Weight (In Ounces)	Cost of Waste Materials from Consumables Distributor	Cost of Waste Materials from Consumables Manufacturer
Unlimited access	8.85	$1.27	$0.55
Limited access	6.94	$1.00	$0.43

Note: Unlimited access – students were not restricted in their use of electrodes;
Limited access – students could only use an additional electrode if the remainder of the prior electrode was less than two inches.

Conclusions, Discussion, & Limitations of the Study

The underlying purpose of the present study was to describe the effects that the use of an alternative welding consumable management strategy would have on students' consumption of welding electrodes**.** Data pertaining to objective one of the study, determining students' welding consumables usage when employing differing consumables management strategies, indicate that the differences between each management strategy did not differ greatly in terms of waste materials produced, though fewer electrodes were used when the limited access strategy was utilized, as could be expected. Regarding objective two, the evaluation of the cost-effectiveness of limiting students' access to using consumable welding electrodes, the cost savings between each management strategy were minimal at best. More specifically, savings of $0.27 and $0.12 were seen when purchasing electrodes from a welding supply distributor and a welding supply manufacturer, respectively.

The results of the present study indicate that developing a protocol to provide a form of behavioral control (i.e., the use of an intensive welding consumable micromanagement strategy) can help to sway the behaviors (e.g., limiting the use of consumable welding electrodes) of those involved. These findings are in congruence with Ajzen's (1985) theory of planned behavior. Further, this micromanagement strategy practice could provide a new method of developing students' abilities to self-regulate and more frugally manage limited supplies. This improved practice aligns with Roberts, Harder, & Brashears (2016) suggestion that more innovative practices, concepts, and ideas can yield practical results within agricultural education settings, including SBAE. For example, though considerable fiscal savings were not yielded in the present study, consumable electrode usage decreased through the use of the limited access micromanagement strategy. Perhaps the use of this management strategy over a longer period of time (i.e., over a full semester or academic year) with a larger population of students would yield greater cost and electrode waste savings.

It should be noted that, in accordance with Table 2, there was significant variation in welding electrode lengths throughout the duration of the study. It could be assumed that as students began to gain additional experience in the welding process, their efficiency in using electrodes would have improved over time. However, some of these results seem almost contradictory in nature, especially during the latter half of the experiment. Perhaps the participants within the present study experienced the Hawthorne effect. As described by Leonard and Masatu (2006), the possibility exists that these students deliberately adapted their behavior so as to influence the results of the present study. It is conceivable that direct contact with the lead researcher of the present study, who was also the program's agricultural education teacher, may have created a desire to perform the welding activities in an atypical fashion. This should be recognized as a limitation of the present study.

Regarding additional limitations of the study, it should be noted that because the population of this study was only one class that consisted of eight ($N = 8$) secondary students, these findings are not generalizable beyond this population. Moreover, the short duration of the study, the use of subjects from only one SBAE program, the accounting of the possibility of the Hawthorne Effect, and the lack of randomization of subjects contribute to this list of limitations as well. Future replications of this study should work to control these factors whenever possible. It should also be noted that weld quality was not addressed within the present study. The agricultural education teacher noted that when the micromanagement consumables management strategy was used, the student participants' weld quality produced appeared to deteriorate. As such, if the fiscal savings between each management strategy were minimal and weld quality suffered, perhaps the use of an intensive micromanagement strategy, in this particular case, actually harmed the student participants' development and acquisition of welding skills.

Recommendations for Practice & Research

Regarding recommendations for welding instructors, the researchers suggest that welding teachers work directly with welding supply manufacturers to procure consumable electrodes. As described within the present study, some differences in costs existed between purchasing from welding supply distributors versus from manufacturers. Teaching budgets could benefit greatly from these potential savings (McKim & Saucier, 2013; Saucier et al., 2014) Also, the researchers, based upon the results of the present study, recommend that teachers proactively manage metal utilization instead of consumable electrode usage during SMAW training. As metal for welding could be expected to cost more than any other welding-related consumable, budgets should be protected with effective and efficient practices that best utilize available resources (McKim & Saucier, 2013; Saucier et al., 2014). Further, more intensive management of consumable materials used in welding activities may influence the practices and management methods used by students. As secondary students will be taking roles within the workforce in the near future, perhaps developing resource conservation practices at an early age could positively influence these behaviors in the future, potentially aiding future employers in controlling costs. Roberts et al. (2016) described how new and innovative practices can bring about positive change in a variety of environments. Perhaps the teaching and use of intensive management strategies could help to fit within this role as well.

Recommendations for post-secondary welding personnel, teacher educators, and industry-based practitioners and educators vary slightly. Regarding professionals involved in post-secondary welding instruction, perhaps the abovementioned management strategies should be implemented into post-secondary laboratory settings as well. Such actions could help to reduce laboratory teaching expenditures, as well as communicate the importance of resource conservation and management. Teacher educators may also find value in such practices as well, as the need for effective laboratory management is constantly present (Saucier et al., 2014). Further, as laboratory instruction includes additional environments and contexts beyond welding (Phipps et al., 2008; Shoulders & Myers, 2012), perhaps developing effective consumables management competencies of preservice teachers would be suitable as a part of teacher preparation. Moreover, developing a conservation-based mindset within preservice teachers could aid in laboratory teaching cost management skills during the early career teaching phase. Industry-based practitioners and educators could also implement and emphasize management strategies that work to reduce materials consumption when training novice employees as well as customers. Such practices could grant greater cost controls that may, over time, provide a significant return on this training investment.

For future research endeavors, the researchers suggest that this study be replicated using a true experimental design. As described by Ary, Jacobs, & Sorensen (2010), experimental research allows for a more concrete method "for demonstrating cause-and-effect relationships" (p. 271). Through helping to control for selected elements of internal validity, randomizing subjects would increase the overall rigor of a replication of the present study, as well as provide an increase in the quality of the data collection process (Ary et al., 2010). Also, future replications should seek to use multiple laboratory environments and be conducted over a longer period of time (i.e., a nine week-quarter, a semester, or an academic year) so as to further increase the size and scope of the study. The researchers also advise that future replications should consider examining an intensive management strategy focused upon metal usage so as to examine the effects associated with conserving metal during welding training procedures.

References

Ajzen, I. (1985). From intentions to action: A theory of planned behavior. In J. Kuhl & J. Beckman (Eds.), *Action control: From cognitions to behaviors* (p. 11–39). New York, NY: Springer.

Anderson, R., Velez, J., & Anderson, S. (2014). Using the health belief model to comparatively examine the welding safety beliefs of postsecondary agricultural education students and their non-agricultural education peers. *Journal of Career and Technical Education Research, 39*(1), 9-22. doi: https://doi.org/10.5328/cter39.1.9

Ary, D., Jacobs, L., & Sorensen, C. (2010). *Introduction to research in education*. (8th ed.). Belmont, CA: Wadsworth, Cengage Learning.

Burris, S., Robinson, J. S., & Terry, R. (2005). Preparation of pre-service teachers in agricultural mechanics. *Journal of Agricultural Education, 46*(3), 23-34. doi:10.5032jae/2005.03023

Herren, R. V. (2015). *Agricultural mechanics: Fundamentals and applications* (7th ed.). Stamford, CT: Cengage Learning.

Leonard, K., & Masatu, M. C. (2006). Outpatient process quality evaluation and the Hawthorne Effect. *Social Science & Medicine, 63*, 2330-2340. doi: 10.1016/j.socscimed.2006.06.003

Madden, T. J., Ellen, P. S., & Ajzen, I. (1992). A comparison of the theory of planned behavior and the theory of reasoned action. *Personality and Social Psychology Bulletin, 18*(1), 3-9. Retrieved from https://www.researchgate.net/profile/Icek_Ajzen/publication/248825016_A_Comparison_of_the_Theory_of_Planned_Behavior_and_the_Theory_of_Reasoned_Action/links/0f317539f25d619676000000.pdf

McCubbins, OP, Anderson, R. G., Paulsen, T. H., & Wells, T. (2016). Teacher-perceived adequacy of tools and equipment available to teach agricultural mechanics. *Journal of Agricultural Education, 57*(3), 223-236. doi: 10.5032/jae.2016.03223

McKim, B. R., & Saucier, P. R. (2012). A multi-state factor-analytic and psychometric meta-analysis of agricultural mechanics laboratory management competencies. *Journal of Agricultural Education, 53*(2), 139-152. doi: 10.5032/jae.2012.02139

McKim, B. R., & Saucier, P. R. (2013). A 20-year comparison of teachers' agricultural mechanics laboratory management competency. *Journal of Agricultural Education, 54*(1), 153-166. doi: 10.5032/jae.2013.01153

Phipps, L. J., Osborne, E. W., Dyer, J. E., & Ball, A. (2008). *Handbook on agricultural education in public schools* (6th ed.). Clifton Park, NY: Thomson Delmar Learning.

Roberts, T. G., Harder, A., & Brashears, M. T. (Eds). (2016). American Association for Agricultural Education national research agenda: 2016-2020. Gainesville, FL: Department of Agricultural Education and Communication. Retrieved from http://www.aaaeonline.org/resources/Documents/AAAE_National_Research_Agenda_2016-2020.pdf

Saucier, P. R., Vincent, S. K., & Anderson, R. G. (2014). Laboratory safety needs of Kentucky school-based agricultural mechanics teachers. *Journal of Agricultural Education, 55*(2), 184-200. doi: 10.5032/jae.2014.02184

Shoulders, C. W., & Myers, B. E. (2012). Teachers' use of agricultural laboratories in secondary agricultural education. *Journal of Agricultural Education, 53*(2), 124-138. doi: 10.5032/jae.2012.02124

Shultz, M. J., Anderson, R. G., Shultz, A. J., & Paulsen, T. H. (2014). Importance and capability of teaching agricultural mechanics as perceived by secondary agricultural educators. *Journal of Agricultural Education, 55*(2), 48-65. doi: 10.5032/jae.2014.02048

The ESAB Group, Inc. (2000). *Basic welding filler metal technology: A correspondence course: Lesson XI: Estimating and comparing weld metal costs*. Retrieved from http://www.esabna.com/euweb/awtc/lesson9_1.htm

Wells, T., Perry, D. K., Anderson, R. G., & Shultz, M. J., & Paulsen, T. H. (2013). Does prior experience in secondary agricultural mechanics affect pre-service agricultural education teachers' intentions to enroll in post-secondary agricultural mechanics coursework? *Journal of Agricultural Education, 54*(4), 222-237. doi: 10.5032/jae.2013.04222