BENCH-TOP AND INDUSTRIAL METAL LATHES: DIFFERENCES AND SIMILARITIES

Alex Johnson and David Yearwood, University of North Dakota

Abstract

Educators have extensively debated the importance of teaching machining fundamentals in engineering curricula. Some argue that hands-on skills are a thing of the past and engineers today need to concentrate more on core courses dealing with solid mechanics, dynamics, thermo, materials, along with exposure to design. Machining curricula, while still technically a part of many programs, have lost emphasis, perhaps in response to increased costs. This is not surprising given the high operating expenses associated with maintaining industrial laboratories containing equipment needed to provide students with experiential learning in manufacturing processes. Severe budgetary constraints have resulted in many schools trying to do more with less, and maintaining expensive laboratories with equipment that many feel is unnecessary becomes difficult to justify. Still, there is plenty of evidence to suggest that 21st century engineers can benefit from manufacturing curricula that include components of experiential learning.

A study was conducted at a Midwest university which compared two types of equipment: a bench-top metal lathe and an industrial lathe. Two questions were examined in the study: 1) what effect would the substitution of a 7”x12” bench-top metal lathe have on a student’s ability to produce small-scale parts within a .005” tolerance range? And, 2) what were students’ perceptions regarding the advantages and/or disadvantages associated with using a bench-top metal lathe compared to an industrial lathe in an educational setting? The results indicated that there were no statistically significant differences between parts produced on the bench-top and industrial metal lathe. Students, however, perceived the use of the bench-top metal lathe to be a suitable replacement for the industrial metal lathe.

Introduction

Mr. President, There is No Engineer Shortage, was the title of a recent article in the Washington Post by Wadhwa [1]. However, Brown [2] notes that Swoboda, a company that employs engineers, reports having some difficulty finding engineers with the skill sets necessary to keep their factory in peak operation. John Fuhs, vice president of sales and engineering at Swoboda, said that they are having a hard time finding “engineers who don’t mind working at a desk on the factory floor and implementing as well as designing projects” [2]. Fuhs goes on to say that his company prefers student interns from Germany who, he states, “know how to do their own CAD, machine design, and basic tool making. They’ll walk into a tool room and immediately start working” [2]. The experiences that Swoboda encountered are supported by studies conducted by the University of California at Berkeley, which, during the course of several interviews with machinists and engineers, found that the general belief was that engineering programs should continue to teach manual machining processes [3]. Clearly, program goals and needs will differ with some choosing to focus more on theory and less on application. Examples of the varying approaches can be found in programs ranging from engineering—with more of a focus on theory—to technology, industrial technology, and secondary STEM-based programs that use differing levels of theory mixed with application.

Specialized equipment found in most engineering and technology programs represents a sizable amount of a department’s budgetary expenditures, including indirect costs associated with having appropriate facilities to house this equipment. A report submitted to the Ohio Legislative Office of Educational Oversight [4] and a later study sponsored by MPR Associates in Berkeley, CA, [5] suggest that such costs may account for the relatively high price of engineering in the U.S. Given the current state of the economy, where federal and state governments are running huge deficits, this raises some concern about the long-term viability of these agencies to continue funding engineering and manufacturing programs.

Helping students acquire the necessary skills and knowledge needed for success within the work environment is a requirement of engineering/manufacturing programs, and finding ways to bring this about will require some creative thinking in lieu of using modern, costly equipment. Therefore, programs, with limited budgets, may have to become creative by resorting to more cost-effective approaches if they are to avoid becoming targets for budget cuts. Additionally, it is important to ensure that any cost-saving measures undertaken do not negatively impact program offerings and that equipment selection will still satisfactorily prepare students to enter the job market as qualified employees.

One viable alternative to costly industrial equipment may be to employ the use of virtual systems, but Carnevale [6] raises some question about the viability of virtual environments to provide students with the same skill sets that traditional methods of instruction could deliver. While the equipment needed by engineering/manufacturing programs may be expensive, there are less costly alternatives. One such alternative exists in the form of bench-top machine tools. Bench-top machine tools operate in a similar fashion to their full-size cousins; they have similar controls and are also much more compact and inexpensive than their full-size counterparts.

A recent study conducted at a Midwestern university's Department of Technology suggests that engineering/manufacturing programs facing budget cuts may be able to substitute bench-top metal lathes for the more expensive industrial-size equipment without negatively impacting the effectiveness of their programs. Bench-top metal lathes were selected for this study because of their reduced cost compared to an industrial lathe and their functional versatility, which includes machining operations such as turning, drilling, and milling. The ultimate goal of this study was to examine the feasibility of using bench-top metal lathes as a cost-effective alternative for industrial metal lathes in educational settings, without negatively impacting the quality of the program.

There are differences that exist between bench-top and industrial lathes. Size and price are certainly the most obvious; however, there are differences in features as well. Table 1 shows a comparison between the bench-top and the industrial lathes used in this study. In both instances, the exact model machines that were used in the study are no longer manufactured; however, equivalent systems were priced for comparison purposes. The specifications shown here are the same as the machines used in this study.

As Table 1 shows, the two types of lathes have many similarities and can perform similar tasks as long as the size of the work being done fits into the physical parameters of the bench-top lathe. It is important to note, however, that the prices shown are reflective of what an equivalent machine, with similar features, would cost today. Prices do vary depending on the manufacturer and machine specifications. For example, the bench-top lathe used in this study is one of the least expensive models on the market; other brands, such as some European-made machines, can cost several thousand dollars and is in the price of many mid-range industrial-size lathes. An equivalent industrial lathe produced in China can be purchased for around $8,000-$10,000. These import lathes generally have more accessories than the U.S.-built Clausing lathe used in this study.

Table 1. Bench-top Lathe and Industrial Lathe Comparisons

Specifications	Industrial Lathe Clausing 1300	Bench Lathe Cummins 7x12
Manufacturer	Clausing	Seig
Country of origin	United States	China
Swing over bed	13 inches	7 inches
Distance between Centers	24 inches	12 inches
Spindle bore	1 5/16 inches	.80 inches
Tailstock taper	3 MT	2 MT
Spindle taper	3 MT	3 MT
Tailstock travel	4.25 inches	2.5 inches
Cross-slide travel	6.75 inches	2.75 inches
Motor	5 HP	1/3 HP
Electrical	230 Volt 3 ph 60 Amp	110 Volt 10 Amp
Speed range	45-2000 RPM	0-2500 RPM
Drive	Hydraulic	Variable Speed
Range of threads	4-224 TPI	12-52 TPI
Gearbox	Quick change	Manual
Standard Accessories	Wrenches, oiler Other accessories must be ordered separately	3 jaw chuck, face plate, steady rest, turret post, change gears, dead center, wrenches
Net weight	1415 pounds	74 pounds
Footprint	33 x 60 inches	28 x 9 inches
Price in 2012	$12, 970	$595.00

For purposes of this study, a bench-top lathe was defined as a lathe designed for hobby or personal use and is theoretically capable of turning a cylinder that would not exceed 7 inches in diameter and 12 inches in length. In addition, the weight of the lathe would not exceed 100 pounds and so would be relatively portable. These limitations would allow for relatively easy storage and would not take up a lot of valuable facility space. Industrial lathes were defined as those lathes that are designed for heavy, production use within industry. The physical turning capacity that these lathes could handle would be in excess of 12 inches in diameter and 24 inches in length. The weight of the lathe would exceed 1200 pounds.

The following two questions were examined in this study.

1. What effect will the substitution of a 7”x12” bench-top metal lathe have on a student’s ability to produce small-scale parts within a .005” tolerance range when compared to similar parts manufactured with industrial metal lathes?

2. What will students perceive as the main advantages and/or disadvantages associated with using a bench-top metal lathe in an educational setting when compared to the larger industrial metal lathe?

Historical Perspective

In the early years of American education, the common view of what a college education should provide—essentially the view held by educated, wealthy Americans—was quite different from the goal of education held by the middle and lower classes. Interestingly, parents who lacked formal educations but publically scoffed at higher education, still wanted their children to attend college and receive a degree that would provide advantages that they themselves did not achieve [7].

Interest in practical education—a trade obtained through an apprenticeship program—was not without its opponents. The differences between skilled labor and educated labor were largely due to the kind of education that the workmen received [8]. Under the terms of the Morrill Act, programs in the new colleges were supposed to follow a pattern of genuine work and students were not to be bothered with what was called “play work”. The term play work, which was commonly used at that time to refer to a type of work that did not create what today is referred to as authentic learning tasks, is a subset of situated cognition [9]. Two of the central points of situated cognition theory are that learning environments should re-create the types of environment in which students will be working, and that the work performed within these environments should be the same type of work that will be expected of them when they enter the workforce. This view is consistent with that of education reflected in earlier apprenticeship programs, but it was not always consistent with the perception of education that many of the institutions of higher education of the day shared [10].

Apprenticeship programs were popular because they effectively trained students for the world of work in the trades. Therefore, it was not surprising that many of the industrial education programs started to integrate the concepts of an apprenticeship within their curricula. In this fashion, apprenticeships eventually became the foundations for cooperative education [11]. However, higher education of the day was most commonly focused on theoretical sciences and classical literature and, therefore, placed less emphasis on application or experiential learning activities. With the passage of the Morrill Act, higher education was forced to explore other options, as federal dollars were available only if colleges instituted these new curricula—applied agricultural and engineering. As a result, higher education changed its curricular focus in order to acquire the funds created by the Morrill act. And, this change necessitated hiring individuals who were skilled in industrial practices of the day. Such instructors were best able to ascertain whether the principles of science and mathematics taught in these programs were applicable to industry or whether they were mere play work that would not benefit the students, thereby ensuring “equal cultivation of the head, the heart, and the hands as representing a totality and completeness of instruction” [8]. The intent with industrial education was not to supplement a liberal education but rather to provide students with both a liberal and a practical education [12].

Educational movements are like pendulum swings, constantly changing direction but eventually returning to their earlier position. Though at one time industrial education supporters encouraged curricula that provided students with practical skill sets that could be immediately used in industry, one possible explanation is that the pendulum has swung to the other side in light of observations made by Swoboda [2]. It is rather interesting to note that similar thoughts were expressed in a Berkley study which suggested that little changed between 1992 and 2009 [3]. Engineering and manufacturing students who understand all of these subjects—solid mechanics, dynamics, etc.—while still being capable of operating the machine tools necessary for the construction of prototypes are more apt to make better decisions concerning design and relate better to other employees within the companies for which they work. One thing the present economy has demonstrated is that employees of the 21st century need to be able to adapt, and engineering/manufacturing programs must provide more flexibility in their curricula to ensure that students leave these institutions well prepared for the world that awaits them.

Methodology

Data Sources

Thirty-three students enrolled in an introductory manufacturing process course at an upper Midwestern university participated in an experiment designed to study the use of bench-top equipment as viable substitutes for an industrial-size machine. The survey developed for the study was administered online via Survey Monkey and included an adaptive feature which allowed for certain questions to be skipped when study participants selected a 'not applicable selection' response to any question on the instrument. For example, one question on the survey asked: "Have you used any kind of metal lathes?" A person who provided a negative response to the question would then skip the next four questions since they pertained to experience using metal lathes.

The instrument designed for the study was divided into four sections with the first section providing demographic information (13 items) related to gender, employment history, and educational level achieved. The three other sections of the student survey provided data about the three perception areas of tolerance, suitability of task, and comfort level (20 items). Section II of the survey contained six tolerance questions and required students to take measurements on a machined test bushing using both bench-top and industrial lathes. Each student attempted to manufacture the test bushing within the specified tolerance range of .005" (5 thousandths of an inch), which was determined based on the general tolerance requirements for a steam engine produced in an entry-level production processes class taught in the Technology Department at the university. All testing was conducted using the same two machines, one of which was a bench-top metal lathe and the other one being an industrial metal lathe.

Section III of the survey was designed to collect data about students' perceptions concerning the suitability of bench-top metal lathes when used in an educational setting. The nine Likert-type questions focused on:

- durability (construction, rigidity);
- suitability for teaching fundamental concepts of metal turning; and,
- machine specifications, such as controls and physical limitations on size of material that can be machined.

Section IV of the survey collected information about students' perceptions concerning issues of safety and comfort level with regards to working with the two lathes. Six Likert -type and short-answer response questions in this section focused on design/ergonomic issues of bench-top and industrial-size metal lathes and also the safety features found on both lathes.

Two questions guided the study: 1) what effect will the substitution of a 7"x12" bench-top metal lathe have on a student's ability to produce small-scale parts within a .005" tolerance range when compared to (their ability to produce) similar parts manufactured with an industrial metal lathe? And 2) what will students perceive as the main advantage and/or disadvantage associated with using a bench-top metal lathe in an educational setting when compared to a larger industrial metal lathe? The survey instrument was designed to help answer questions 1 and 2 of the study, and a pilot study was conducted to provide comparison data for research question 2 relative to the tolerances that could be achieved when manufacturing an aluminum stock on both the industrial and bench-top lathes.

Experiment

Prior to conducting the experiment, students were required to perform calibration settings on both of the lathes used in this study. Spindle speeds for both lathes were calibrated using a digital laser non-contact tachometer. An insert tool (TT style C2 grade carbide) was selected and installed in a tool holder that both lathes could accommodate and a sheet steel template was used to ensure that the tool angle was the same throughout the calibration process. Throughout the manufacturing phase of the study, the insert tool was replaced every time a new part was created in order to reduce the effects of tool wear on the process.

In order to obtain comparison data for the study, 66 bushings were created. Each student was asked to produce a total of two bushings, one using a 7"x12" bench-top metal lathe and the other on a 13"x24" industrial lathe. Following the lathe work, students were asked to take three measurements on each bushing. These measurements were:

1. The outside diameter;
2. The step diameter;
3. And the step length.

Participants

Thirty-two male students and one female student participated in the study. Students' work experiences varied, with seven (21.2%) students having worked in industry/business, two (6.1%) worked in education, 22 (66.7%) classified themselves as full-time students, and two (6.1%) students classified themselves as other. The students' highest level of educational experience varied, with 25 students (75.8%) having completed college courses without earning degrees, two (6.1%) as having an Associate of Science degree, three (9.1%) having completed a BA or BS degree, and three (9.1%) having obtained a technical certificate or degree. The students' level of training using machine tools varied, with a majority of them, 16 (64%), having received training at the college level. Eight students (32%) received training in high school, and the remaining students obtained training either in a technical school, they attended a workshop, or obtained training elsewhere. Only 23 participants (69.7%) stated that they used metal lathes. A majority of them (21 students) had less than two years' experience using a bench-top lathe. A smaller number, 17 students, indicated that they had experience working with larger industrial lathes. The selection of these students was important to this study because an earlier pilot study demonstrated that students who had a considerable amount of experience using metal lathes were able to successfully produce a product with a better tolerance range than students achieved in the study. Therefore, having students with varying experiences conduct similar work with metal lathes was needed in order to determine what role experience would play in producing a product that was within a .005" tolerance range on either lathe used in this study.

Data Collection

Data collection for the student portion of the study involved a brief training session on the use of the bench-top metal lathe, including a demonstration on the manufacture of the test bushing of the same dimensions that each student would be manufacturing on both test machines. Students were then allowed to participate in a two-hour laboratory activity in which they fabricated a test bushing on both the bench-top and the industrial lathes for a total of two bushings per student. Following the manufacture of each bushing, each student measured and recorded the physical dimensions of the bushing. When students completed the laboratory portion, they were asked to respond to the 34 items on the questionnaire. Each student spent approximately four hours participating in the study.

Data Preparation

Questionnaires were first viewed to identify any inconsistencies or missing data. Responses with missing information are generally not considered valid for statistical analysis [13], and consequently those responses were not included in this study. Data preparation included data coding, data entry, and verification. To ensure that data were entered correctly, every fifth questionnaire was checked for errors, once all of the data were entered.

Data Analysis

Analysis for this study was co-relational, using the physical dimensions from each student's test bushings as a co-variable that was compared to the same student's preference for the style of lathe she/he used. To analyze the data, a variety of statistical tests were performed such as descriptive statistics and Pearson correlation. In addition, a Multivariate Analysis Of Variance, or MANOVA, was considered to determine the difference between the criterion variables and demographics. The reliability of the three component sections of the Likert-scale portion of the questionnaire was determined following the pilot study using Cronbach's Alpha values and the responses from the pilot study.

Validity and Reliability

Faculty, industry personnel, and students not part of the study, assisted in reviewing a draft of the survey instrument. These individuals also commented on question clarity and content, including directions for the survey and its layout. These comments aided in improving the internal validity and the reliability of the non-demographic sections of the instrument. The reliability of the three component sections of the Likert-scale portion of the questionnaire was determined from the Cronbach's Alpha values obtained from data acquired from a pilot study.

Summary of Findings

Research Question 1

The first research question examined the effect that the substitution of a bench-top metal lathe would have on a student's ability to produce small-scale parts within a .005" tolerance range when compared to similar parts manufactured with the industrial metal lathe. Following a training session on the use of the metal lathe and a demonstration on the manufacture of the test bearing, shown in Figure 1 below, thirty-three student participants were asked to make one bushing each on the bench-top and industrial lathes. Following this, they were asked to record measurements for the outside diameter, step diameter, and step length. These measurements were also taken by the researcher. Summary statistics for the data are shown in Tables 2 through 4.

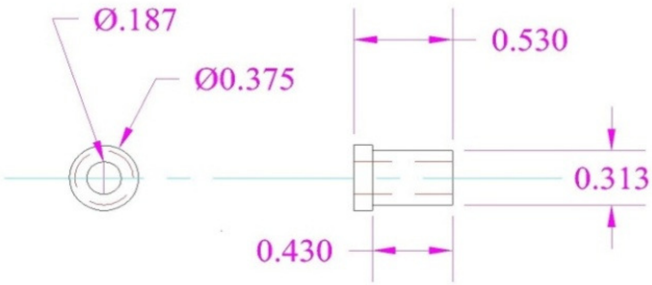

Figure 1. Test Bearing

Table 2. Summary Statistics Outside Diameter (n=33)

	Outside Diameter Industrial Lathe	Outside Diameter Bench Lathe
Count	33	33
Average	0.380	0.379
Standard Deviation	0.010	0.004
Minimum	0.365 inches	0.372 inches
Maximum	0.425 inches	0.388 inches
Range	0.060 inches	0.016 inches
Stnd. Skewness	9.385	0.456
Stnd. Kurtosis	24.480	0.013

Table 3. Summary Statistics Step Diameter (n=33)

	Step Diameter Industrial Lathe	Step Diameter Bench Lathe
Count	33	33
Average	0.312	0.311
Standard Deviation	0.003	0.003
Minimum	0.302 inches	0.302 inches
Maximum	0.315 inches	0.319 inches
Range	0.013 inches	0.017 inches
Stnd. Skewness	-4.059	-1.157
Stnd. Kurtosis	5.137	3.572

Examination of the data revealed that, in almost all instances, the data exhibited a departure from normality. The one exception to this was the outside diameter data from the bench-top lathe. Since the data set was found not to come from a normal distribution, it was not possible to run a standard t-test on this data. Instead, a Mann-Whitney Wilcoxon test was performed, as it does not require normal distributions. The results of the Whitney test showed that there was no statistically significant difference between the two medians at a 95% confidence level.

Not all data that is collected for analysis is normally distributed. In industry, this is a common problem. Generally, the cause for the non-normality should be determined and actions taken to address the problems. Common problems that lead to non-normally distributed data in industry can include extreme values that result in skewed distribution. Another common problem deals with the overlap of two processes. This commonly occurs when an operator changes positions or a shift change occurs. When this happens, two or more data sets that might alone be normally distributed are combined and two different frequent values may cause the data to look bimodal.

Table 4. Summary Statistics Step Length (n=33)

	Step Length Industrial Lathe	Step Length Bench Lathe
Count	33	33
Average	0.385	0.387
Standard Deviation	0.011	0.010
Minimum	0.362 inches	0.356 inches
Maximum	0.425 inches	0.413 inches
Range	0.63 inches	0.057 inches
Stnd. Skewness	2.058	-2.499
Stnd. Kurtosis	4.522	4.993

In the case of the above data, it is likely that similar situations did occur. With 33 students each performing a complete task, the fluctuation of the data is not surprising. Also, new, relatively inexperienced students performing introductory machining operations oftentimes make mistakes, which can explain the number of outliers that are present in the data sets. These outliers are easily seen in Figures 2 through 4.

Though it was not possible to perform a standard t-test on the data due to the normality of the distributions, it should be noted that the removal of the outliers resulted in normal distribution patterns. Consequently, a t-test comparing the means showed that there was no statistically significant difference between the different data sets at a 95% confidence level. While removing these outliers does allow the use of a standard t-test, it also results in the loss of data points on what is already a small sample. For this reason, it is not a recommended practice. However, the data were manipulated here to show the impact that these outliers have on the statistical analysis.

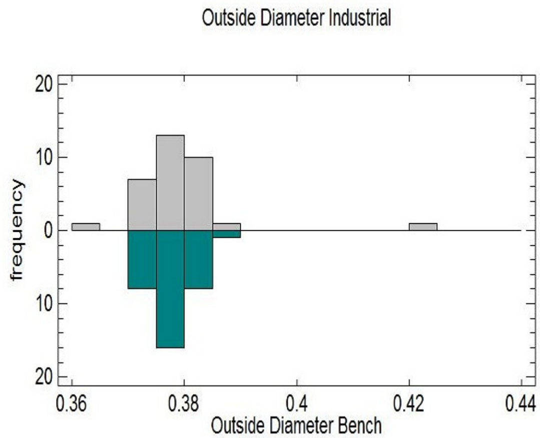

Figure 2. Outside Diameter Histogram for Bench-top and Industrial Lathes

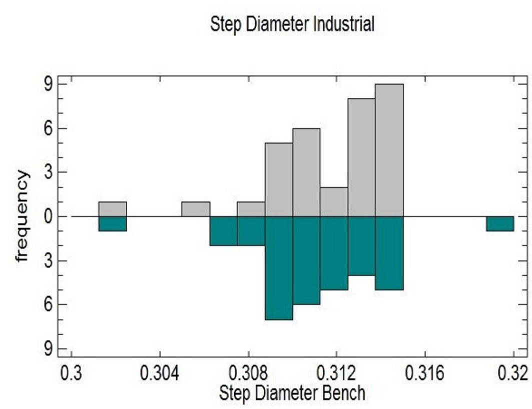

Figure 3. Step Diameter Histogram for Bench-top and Industrial Lathes

Pilot Study

In an earlier pilot study, two graduate students, who had some experience with metal lathe operation, performed the tests. Each graduate student fabricated 30 bushings on both the bench-top lathe as well as the industrial lathe used in this study. From each bushing produced, measurements were taken from the outside diameter, step diameter, and step length. Tables 5 and 6 show summary statistics for data collected from the outside diameter and also the step diameter. Analysis of standard skewness and standard kurtosis indicated that both sample sets were normally distributed. Following this, a t-test was run to compare the means, which showed that there was no significant difference at a 95% confidence level.

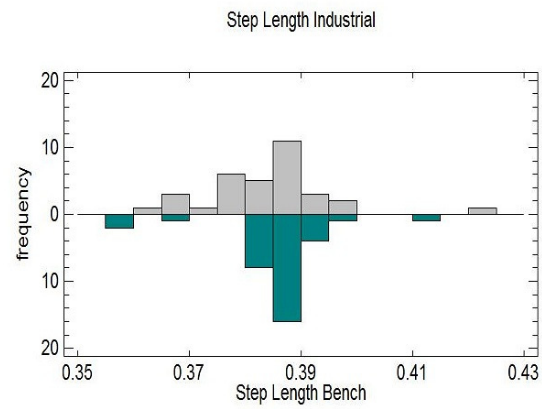

Figure 4. Step Length Histogram for Bench-top and Industrial Lathes

Table 5. Summary Statistics Outside Diameter (n=30)

	Outside Diameter Industrial Lathe	Outside Diameter Bench Lathe
Count	30	30
Average	0.351	0.350
Standard Deviation	0.003	0.002
Minimum	0.343 inches	0.347 inches
Maximum	0.355 inches	0.353 inches
Range	0.012 inches	0.006 inches
Stnd. Skewness	-1.934	-0.139
Stnd. Kurtosis	0.736	-1.148

Data collected from the step length measurements were found to have more variance. Summary statistics for the step lengths can be seen in Table 7. These data were found to show some departures from normality for both the bench-top and industrial lathes.

Since the data set was found not to come from a normal distribution, it was not possible to run a standard t-test on these data. Instead a Mann-Whitney Wilcoxon test was performed, as this does not require normal distributions. The results of the Whitney test showed that there was not a statistically significant difference between the two medians at a 95% confidence level.

Table 6. Summary Statistics Step Diameter (n=30)

	Step Diameter Industrial Lathe	Step Diameter Bench Lathe
Count	30	30
Average	0.313	0.313
Standard Deviation	0.002	0.002
Minimum	0.308 inches	0.308 inches
Maximum	0.318 inches	0.318 inches
Range	0.010 inches	0.010 inches
Stnd. Skewness	-0.059	-0.539
Stnd. Kurtosis	-0.385	0.112

Table 7. Summary Statistics Step Length (n=30)

	Step Length Industrial Lathe	Step Length Bench Lathe
Count	30	30
Average	0.237	0.239
Standard Deviation	0.010	0.008
Minimum	0.213 inches	0.208 inches
Maximum	0.253 inches	0.256 inches
Range	0.040 inches	0.048 inches
Stnd. Skewness	-2.065	-3.117
Stnd. Kurtosis	1.035	6.547

Research Question 2

The second research question asked "What will students perceive as the main advantage and/or disadvantage associated with using a bench-top metal lathe in an educational setting when compared to the larger industrial metal lathe?"

One question in the suitability to task section of the survey asks whether students felt that the bench-top lathe used in this experiment was capable of holding tolerances within a .005" range. Seventy-five percent of the students responded that they felt that the bench-top lathe was capable of holding tolerance within a .005" range. Some (21.9%) were neutral in regards to whether the bench-top lathe could hold this tolerance range, and a few (3.1%) disagreed that the lathe was capable of performing within this tolerance range.

A related question asked whether students felt that that the industrial lathe used in this study was capable of holding tolerances within the .005" range, and most (78.8%) felt that this was true, with the remaining (21.2%) being unsure about this issue. Other survey questions examined the controls used on both lathes. One question asked whether students felt that the controls used on the bench-top lathe were easy to use and most (78.2%) felt that they were, with a minority (18.8%) remaining neutral, and a small percentage (3.1%) feeling that they were not. A similar question was asked about the controls on the industrial lathe used in the study and a somewhat lower number (69.6%) of students felt that they were easy to use with others (27.3%) remaining neutral, and a small group (3%) feeling that they were not.

Comfort-Level Questions

Responses to one survey question indicated that the majority of students perceived that one advantage of using a bench-top metal lathe is that they felt it was a safer alternative (75.8%) and less intimidating (62.5%) to use than a full-size industrial lathe. Another survey question asked whether students felt that they learned more effectively when they are comfortable with their surroundings. The majority of the students (75.8%) felt that this was true, while some (21.2%) were unsure whether this was true or not. Only a small percentage (3%) of students felt that they learned more effectively in an uncomfortable environment.

One question on the survey instrument asked which lathe the students found less intimidating to work with. The majority of the students (62.5%) felt that the bench-top lathe was less intimidating to work with, while a much smaller group (15.6%) felt that the industrial late was less intimidating to use. Others (21.9%) felt that there was no difference in this regard between the two lathes. Another survey question explored whether students felt that there were any design issues that made the bench-top lathe inherently unsafe. Eleven students (34.4%) felt it did, while twenty-one students (65.6%) did not feel any design issues made the lathe unsafe.

Question 33 in the survey asked if students felt that the industrial lathe had any design issues that made it unsafe to operate. The response was nearly the same as for the previous question, with eleven students (33.3%) believing there were design issues that made the industrial lathe unsafe, and twenty-two students (66.7%) believing the design issues did not make it unsafe. Question 34 asked students which lathe they would feel safer working on. Six students (18.2%) felt safer using the industrial lathe, fifteen students (45.5%) felt safer using the bench-top lathe, and twelve students (36.4%) felt there was no difference.

Discussion

Analysis of the data revealed some interesting findings regarding the effect that substituting a bench-top metal lathe for an industrial metal lathe may have on a student's ability to produce small scale parts within a .005" tolerance range. Though in many cases students failed to achieve the required +/- .005" tolerance with one or both lathes, statistically there was no significant difference when comparing the two groups. In essence, both machines achieved similar results when used by the group of students in this study. Some students did produce more accurate bushings with one machine than they did with the other. However, a comparison of the number of non-conforming parts produced by students provided little evidence to suggest that one machine produced better results than the other with the exception of the measurements for step length, which is the length of the step diameter.

Of the three recorded measurements, achieving step lengths that were within the acceptable limits proved to be the greatest challenge for students using both lathes. The bench-top lathe produced a higher percentage of parts in which the step length measurements were within tolerance, but many of those parts were barely within tolerance. In contrast, many of the parts produced with the industrial lathe that were not within tolerance came very close to being within the acceptable range of +/-.005". An examination of the means for the bushings produced with each lathe—bench top and industrial—found that even though the measurements were dissimilar, the difference was not statistically significant.

The personal experience of the researcher determined that both lathes are capable of achieving tolerances considerably better than the +/- .005" target that was chosen for this study when either lathe is operated by experienced users. Both machines used in this study had factory test reports that showed them capable of producing work well within this tolerance range. Additional tests were also performed on both machines prior to the study to verify the factory tests. However, a study of this scope was needed in order to determine how both lathes would perform in an academic setting by students with limited experiences. While participants of this study were not expert in the use of the metal lathe, they were nonetheless representative of the skill level of students who would typically enroll in an introductory manufacturing processes class.

The results of this study demonstrated that while both lathes are capable of producing work within a given tolerance range, inexperienced users can produce accurate results using the smaller bench-top lathe. It is reasonable to conclude that if a piece of equipment appears to be intimidating to the user, then there is a greater likelihood that the learner may feel somewhat overwhelmed, resulting in a less than ideal learning environment. A similar conclusion can also be drawn about the perceived safety of a piece of equipment relative to its size. These perceptions were confirmed in student responses to questions related to comfort level and safety. Data obtained from responses to the study indicated that students overwhelmingly agreed that they learn more effectively when they are comfortable with the equipment in the learning environment. It can be argued, however, that students are perhaps not the best judges of the actual safety, equipment potential, and operating capabilities of equipment similar to those used in this study. However, the issue of comfort level is hard to ignore.

Equipment is an important consideration in secondary and post-secondary technology education as tools to facilitate student learning and helping them acquire an understanding of basic manufacturing processes, including an understanding of how certain tools—mills, lathes, CNC machines, etc. —can be used to produce a manufactured product. Any equipment, however, is only as good as the people using it, and students must be properly trained in its use. Equipment, no matter its quality, may be a poor substitute for inadequate teaching. Competent educators utilize tools to enhance the learning experience while providing students with an understanding of relevant theories, thereby ensuring that students can apply the theories to a wide range of problems using selected tools. Ultimately, students need to acquire the knowledge and skills that they should have in order to be proficient in their chosen careers.

Conclusion

This study was designed to determine whether a bench-top lathe can handle tasks in an educational setting that is typically done with industrial lathes. Bench-top lathes, because of their size, have limitations and cannot complete many tasks that an industrial lathe can. For example, if instructors require that students make steam engines with six-inch bores, a bench-top lathe would not be an appropriate tool to use because the necessary parts would be too large. However, because of material costs, a project in an educational setting is more likely to be a small steam engine or similarly sized project that can be made using a bench-top lathe rather than a larger project that would exceed its ability and utilize larger quantities of expensive materials.

Engineering and manufacturing programs may need to be cost effective to survive, but cutting costs at the expense of the quality of programs does not seem to be an acceptable solution. The results of this study suggest that using bench-top lathes in educational settings may provide a more cost-effective alternative to industrial lathes without impacting the quality of programs. Using bench-top metal lathes will allow programs to provide hands-on experience with machine tools rather than utilizing virtual environments to teach machine-shop concepts, which may prevent students from acquiring the same skill sets as they would with traditional methods of instruction [6].

This study suggests that it is possible to use smaller, less expensive bench-top machine tools and still produce results similar to those produced with industrial lathes without the added safety, cost, space, and student/equipment ratio concerns outlined in the Ohio report [4]. And, the use of bench-top lathes as viable substitutes has the added benefit of providing hands-on experience that those in industry believe is important. The study also suggests that substituting bench-top lathes for industrial lathes may make it possible for educational institutions to provide students with the exposure to machine-tool processes that are necessary for manufacturing. Ultimately, individual programs must make choices that are most appropriate for their particular institutions and circumstances.

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Biographies

ALEX JOHNSON is an Assistant Professor in the Department of Technology at the University of North Dakota. He earned his BS from the University of North Dakota, his M.S. degree from the University of North Dakota (Industrial Technology, 2001), and a Ph.D. (Teaching & Learning, 2010) from the University of North Dakota. Dr. Johnson's research interests are in engineering and technology education, manufacturing processes and small wind turbine technology. Dr. Johnson may be reached at ajohnson@business.und.edu

DAVID YEARWOOD is an Associate Professor in the Department of Technology at the University of North Dakota. Dave earned his BS from Bemidji State University, his M.S. degree from the University of North Dakota (Industrial Technology, 1994), and a Ph.D. (Teaching & Learning, 1999) from the University of North Dakota. Dr. Yearwood has two research interests: 1. Electronic Pedagogy—the purposeful use of technological tools in education; and 2. Control or Semi-Automatic Systems for use in commercial and/or consumer settings. Dr. Yearwood is currently teaching at the University of North Dakota and may be reached at Yearwood@und.edu