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Improvement of Students' Performance in Manufacturing Processes Laboratory by Applying Spaced Practice Strategy

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Abstract

In the traditional laboratory sessions of the Manufacturing Processes Laboratory (INME 4056) in the Mechanical Engineering Department at the University of Puerto Rico campus Mayagüez, the experimental practices with lathe and milling machines lack pre-exposure to the processes before the session when the students work with the final project part. This leads to significant errors in the targeted dimensions in the final project part, which also can affect the geometrical tolerances process learning, one of the important assessments to evaluate at the final of the laboratory class. This paper examines how pretraining sessions, following the philosophy of spaced practice, helps to improve the geometrical tolerance in the final part, and the corresponding learning process. The comparison was carried out between two different laboratory sections, one section experimented with the extra training session and the other one only performed the regular training. This paper presents the results from Spring 2019, including qualitative measures, particularly in tolerance gap reduction. The statistical analysis used was a two-sample T-test, and the p-value was 0.443 which indicates the differences between all the % errors of the featured between control and experimental section are not significant.

Introduction

The Manufacturing Processes Laboratory (INME 4056) is required as a complement of the Manufacturing Processes core course at the Mechanical Engineering Department at the University of Puerto Rico campus Mayagüez. This laboratory is a hands-on course taken primarily by students from Mechanical and Industrial Engineering. One of the key projects in the Laboratory is the manufacturing of an aluminum screw and its support. This project was designed with the objective that the students learn how to use the manual lathe and can practice techniques and develop skills in achieving target tolerances in the screw dimensions. The project is carried out and evaluated as a team during the laboratory sessions. Traditionally, this laboratory activity is carried out during two sessions; in the first session half of the time is for an introductory explanation of the use of the manual lathe machine and in the second half the students start a hand on work with the piece. During the second session the students continue with the project so they can finish all the manual lathe operations.

Typically, students have some difficulties to achieve the targeted tolerances and they show some frustration in the mid-term project presentation. To improve the students' performance (primarily measured by tolerance gap) and experience, during the spring 2019 year was planned to apply a spaced practice strategy, which has been reported as an effective teaching and learning approach with higher long-term learning [1]. This technique presents better results in the learning process than only having continuous repetitions [2]. One of the skills that can be evaluated with this technique is the retention interval since the student is exposed to the last training to the final evaluation [3]. Spaced practice strategy can help to reduce the forgetting curve [4] and improve motor skills [5], by enhancing long-term retention when a variety of tasks are required in a laboratory session class [6].

The application of this strategy can periodically train the students in the laboratory, to allow them to develop the skill of manufacturing in the manual process of lathe and be able to reach the targeted tolerances. In this work a preliminary study was executed during the Spring 2019 semester, which consisted of training the students an extra day more than the traditional laboratory session.

Materials and Manufacturing Process

For the single training session study, the lathe machining process (G4003G, Grizzly Industrial) was performed in an aluminum cylinder (see Figure 1) given to each group. Different turning cutting steps were performed to reduce the diameter and facing cuttings to reduce the length of the cylinder. The manufacture of the screw started with the placement of the aluminum cylinder on the lathe. After the cylinder was fixed on the spindle of the lathe, the cutting tool was set at a 45-degree angle to start removing material. The first material removal was on the “flat” faces or length of the cylinder. This reduction was needed since both surfaces were not completely flat due to the preparation of the raw material cylinders for all the groups of the laboratory session. After making both surfaces flat, the team chose one of the faces to be the fixed point of the screw. The aluminum cylinder cannot be removed until it is completely done to avoid decentralization. The amount of the cylinder inside the lathe, working as the fixed point, had to be 0.4in, suggested by the requirements. After the targeted length of the cylinder was obtained, the next step was to set the cutting tool perpendicular to the length of the cylinder and make the diameter reductions. Six significant features were measured for each aluminum screw (in total 8 screws) and compared using the student t-test, with an α of 0.05.

Figure 2 shows the diagram of the screw features and dimensions that are obtained during the laboratory session: screw head diameter (A), screw body diameter (B), screw body and screw connection diameter (C), screw diameter (D), screw head length (E), Screw body length (F), the screw length (G), final total length (H). All the dimensions have tolerances of +/- 0.001 inches. In this figure, it is also showed the screw as a final piece. To achieve the goal of this study, only the measurements A, B, C, D, E, and G were evaluated. The selected targeted feature measurements and descriptions are provided in Table 1.

Figure 1. Shows the aluminum cylinder raw material used in the laboratory to produce the screw

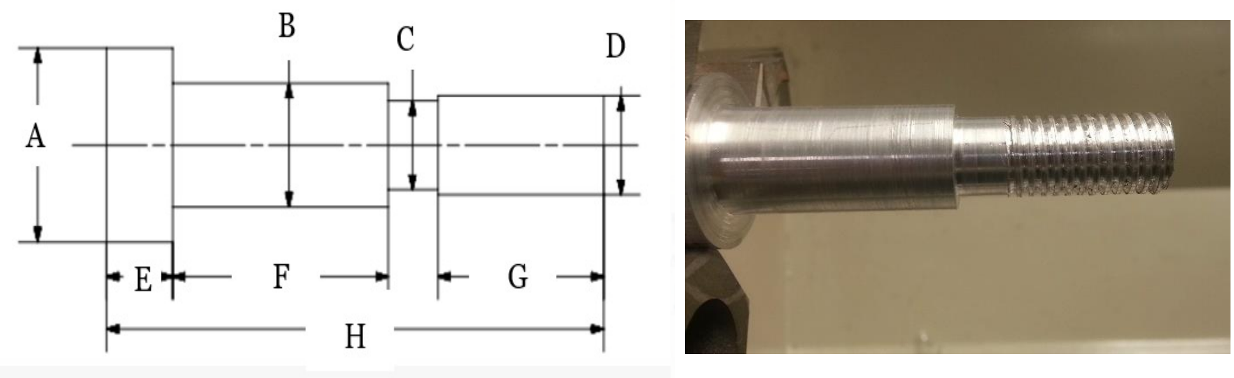

Figure 2. Shows the features of the screw sketch (left) and the final piece (right)

Table 1. Selected feature descriptions measured in the study.

Description	**Feature (Fig. 2)**	**Targeted Dimension (inches)**
Screw head diameter	A	0.980
Screw body diameter	B	0.625
Connecter (body and screw) diameter	C	0.455
Screw diameter	D	0.500
Screw head length	E	0.400
Screw length	G	1.000

Methodology Proposed for Spaced Practice Strategy.

As a security standard in the laboratory, the students take a Security Rules at Laboratory introduction in their first laboratory session. Security glasses, shoes, and clothes are required since the second laboratory class until the end of the course. The working plan consisted of selecting two different laboratory sections, each one with four groups of students and preferably from the same Instructor. One laboratory section had the training sessions (“experimental”) and the other section did not receive the training sessions (“control”) to make the comparison. The condition of selecting the same instructor teaching both sections is to reduce any external noise to the study, such as instructor expertise, etc.

In the extra training the students received an introduction of the lathe machine and started the process of cutting the aluminum piece to get familiar with the material removing process in the order of the millesimal inches (100/1000 inches). During the (second day of training) traditional laboratory session (which includes two days) the students practiced the material reduction process by cutting the length of the cylinder until obtaining tolerances of 10/1000 inches. During the third day of training the students performed the reduction material process (diameters and lengths) reaching tolerances of 1/1000 inches. These stages allowed the spaced practice strategy in the laboratory. Subsequently, the students worked on finishing the screw by a manual process. Once the screws for each team were finished, the students submitted their final dimensions, and the comparisons were performed. The objective is to evaluate if the extra training session of the manual lathe practice should be added to the syllabus of the laboratory, or if additional time outside the laboratory should be required.

Results and Work in Progress

We discovered that having one extra session of training (hands-on) session before the project execution does not lead to a significant reduction in the tolerance gap in the screw dimensions. In Figure 3, it is possible to observe the results of comparison for the mean of all the % errors of experimental and control sessions. It is possible to see that the means and confidence intervals were similar. It was expected to obtain a low mean of % error for the experimental section in all the features. These values are presented in detail in the Appendix. The statistical analysis used was a two-sample T-test, and the p-value was 0.443 which indicates the differences between all the % errors of the featured between control and experimental section are not significant.

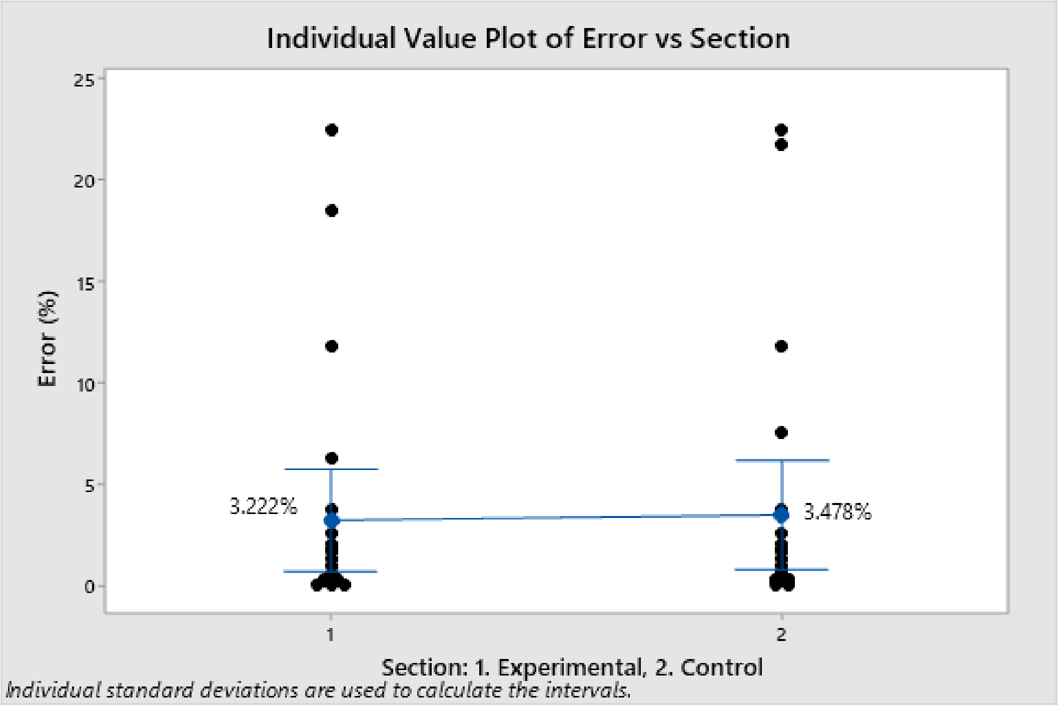

Figure 3. Shows the individual value plot % of error comparison for section 1 (experimental) and section 2 (control).

Because the results are preliminary and inconclusive, we are planning to offer more sessions of training to the students during the Summer 2020 semester. These sessions will consist of at least 3 spaced training sessions before the scheduled session class (traditional). The periodic training will be one training session per week for the “experimental” section, and it will be compared with the “control” section. The student's feedback pointed out that more training sessions could help to improve the approach to achieve the targeted tolerance dimensions. Therefore, a feedback survey will be implemented for the Summer 2020 cohort.

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APPENDIX. Data of the features studied from the workpiece.

	Screw Feature	Expected Measure (inches)	Real Measure (inches)	Error Percentage (%)	Tolerance (-) 0.001	Tolerance (+)0.001	Pass or Fail
Group 1 (Experimental)	A	0.980	0.971	0.92	0.979	0.981	FAIL
	B	0.625	0.625	0.00	0.624	0.626	PASS
	C	0.455	0.448	1.54	0.454	0.456	FAIL
	D	0.500	0.496	0.90	0.499	0.501	FAIL
	E	0.400	0.420	5.00	0.399	0.401	FAIL
	G	1.000	1.039	3.85	0.999	1.001	FAIL
Group 2 (Experimental)	A	0.980	0.978	0.20	0.979	0.981	FAIL
	B	0.625	0.624	0.16	0.624	0.626	PASS
	C	0.455	0.449	1.32	0.454	0.456	FAIL
	D	0.500	0.500	0.00	0.499	0.501	PASS
	E	0.400	0.413	3.25	0.399	0.401	FAIL
	G	1.000	1.020	2.00	0.999	1.001	FAIL
Group 3 (Experimental)	A	0.980	0.980	0.00	0.979	0.981	PASS
	B	0.625	0.624	0.16	0.624	0.626	PASS
	C	0.455	0.456	0.22	0.454	0.456	PASS
	D	0.500	0.500	0.00	0.499	0.501	PASS
	E	0.400	0.490	22.50	0.399	0.401	FAIL
	G	1.000	0.983	1.75	0.999	1.001	FAIL

Group 4 (Experimental)	A	0.980	0.972	0.82	0.979	0.981	FAIL
	B	0.625	0.615	1.60	0.624	0.626	FAIL
	C	0.455	0.461	1.32	0.454	0.456	FAIL
	D	0.500	0.500	0.00	0.499	0.501	PASS
	E	0.400	0.448	12.00	0.399	0.401	FAIL
	G	1.000	0.999	0.10	0.999	1.001	PASS
Group 5 (Control)	A	0.980	0.972	0.82	0.979	0.981	FAIL
	B	0.625	0.626	0.16	0.624	0.626	PASS
	C	0.455	0.455	0.00	0.454	0.456	PASS
	D	0.500	0.498	0.40	0.499	0.501	FAIL
	E	0.400	0.474	18.50	0.399	0.401	FAIL
	G	1.000	1.020	2.00	0.999	1.001	FAIL
Group 6 (Control)	A	0.980	0.979	0.10	0.979	0.981	FAIL
	B	0.625	0.623	0.32	0.624	0.626	FAIL
	C	0.450	0.441	2.00	0.449	0.451	FAIL
	D	0.500	0.500	0.00	0.499	0.501	PASS
	E	0.400	0.425	6.25	0.399	0.401	FAIL
	G	1.000	0.979	2.10	0.999	1.001	FAIL
Group 7 (Control)	A	0.980	1.005	2.55	0.979	0.981	FAIL
	B	0.625	0.621	0.64	0.624	0.626	FAIL
	C	0.455	0.458	0.66	0.454	0.456	FAIL
	D	0.500	0.500	0.00	0.499	0.501	PASS
	E	0.400	0.487	21.75	0.399	0.401	FAIL
	G	1.000	1.031	3.10	0.999	1.001	FAIL
Group 8 (Control)	A	0.980	0.980	0.00	0.979	0.981	PASS
	B	0.625	0.626	0.16	0.624	0.626	PASS
	C	0.455	0.453	0.44	0.454	0.456	FAIL
	D	0.500	0.500	0.00	0.499	0.501	PASS
	E	0.400	0.425	6.25	0.399	0.401	FAIL
	G	1.000	1.000	0.00	0.999	1.001	PASS