AC 2011-1741: THE CREATION AND ASSESSMENT OF A GAGE REPEATABILITY AND REPRODUCIBILITY STUDY EXERCISE IN A METROLOGY CLASS

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The Creation and Assessment of a Gage Repeatability and Reproducibility Study Exercise in a Metrology Class

Abstract

A gage repeatability and reproducibility (R&R) study was implemented in a metrology class in an engineering technology program. An R&R can be a relatively confusing exercise for a student that is new to the concept of gage analysis. This is especially true for students that have limited knowledge of measurement tools and techniques. Care was taken to choose gages that could be analyzed in a straightforward manner. The selection of the type of parts that were to be measured during the exercise was also important. Parts were chosen such that the operators (students) were usually required to determine a specific, controlled method to orient the part to obtain the measured dimension or the results would not yield an acceptable gage analysis ratio. The part limit specifications have a direct bearing on the analysis results and were chosen to yield initial results that might require students to problem solve to improve the measurement technique to achieve an acceptable precision to tolerance ratio. The requirement for the students to improve the measurement process increased the likelihood of a satisfactory learning experience. A survey was created to enable assessment of the exercise. The survey included both quantitative and qualitative measures. Students were typically given the survey before and after the gage R&R exercises. Comparison of the pretest and post test results gave an indication of the relative merits of the exercise.

Introduction

The author teaches a lab-based course in metrology that meets weekly throughout the semester for a total of fifteen three hour sessions. The course structure typically consists of a half-hour lecture followed by a lab exercise in which students work in pairs following a written procedure which directs them to measure given parts with a prescribed measurement tool. The measurements are then used to fill in the blanks provided as part of the written procedure. It was desired to add an R&R to outline the steps that can be taken to characterize the performance of gages and instruments used in a production setting in terms of errors that affect the measurements[1]. A second reason for the R&R was to move students beyond simply performing measurements to a higher level of intellectual behavior by having students apply the information presented to a new problem[2]. A third reason for the R&R was to address student dissatisfaction with the format of the existing written procedure labs. Of all the procedures involved in successfully using team-based learning, the most significant task is creating assignments that further high-level student learning[3]. Additionally, it has been found that student learning increased when multiple experiential techniques were used relative to learning that occurred when a single experiential technique was combined with a lecture format[4].

Activity 1

The initial activity required students to perform an R&R on small screws using a 0-1 inch micrometer to measure the length of the screws. The students were instructed in the general procedure and worked in pairs to perform the measurements. There was a fair amount of

confusion surrounding procedural matters in this initial activity. The data collection and recording methodology was stressed as opposed to the gage passing or failing in the final analysis. This activity took about thirty minutes and was assigned at the end of a regularly scheduled lab that had remaining time. Ten parts were measured three times by each of the two operators. The students were required to search the internet for an R&R spreadsheet into which they could successfully enter their numbers to perform the numerical analysis. They were to then report if their gage passed or failed as judged by the spreadsheet they utilized.

Activity 2

The second activity required the students to measure components of a parallel clamp they had fabricated in a manufacturing processes class.   An assembly drawing of a clamp is shown in figure 1. The twelve students were divided into four teams of three students each. Each of ten parts was measured three times by each of the three operators. This time students were required to select the instrument in the lab that they felt was appropriate for their required measurement. They based their instrument selection on the criteria that it have sufficient precision to discriminate within one tenth of the total part tolerance. There was nearly no confusion about the procedure to be followed but the students were very concerned about their chosen instrument being capable in the final analysis. They seemed to have a greater investment in the outcome since they had selected the measuring device in this exercise. The teams noticed that the procedure used to measure the parts had an impact on the variation of the values obtained. They would coordinate amongst themselves how the part and gage should be oriented to minimize measurement variation. One team started measuring with a rule which theoretically had sufficient discrimination, but found that in practice a more precise measuring instrument was required. The students were required to enter their data into a gage R&R spreadsheet obtained from the internet and to write a brief paper on the meaning of the %EV, %AV and %RR values obtained.
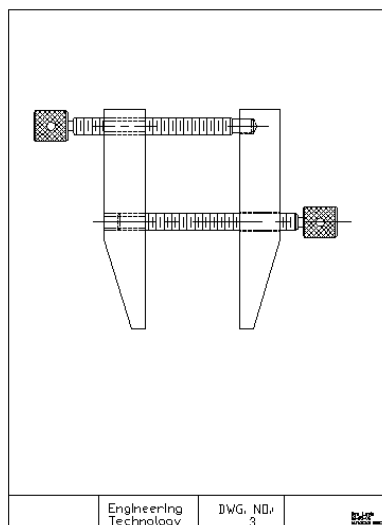

Figure 1 – Clamp assembly drawing

Activity 3

Air gages were the topic of the class for the third activity. An example air gage column is shown in figure 2. Students worked in pairs to perform an analysis of dimensions that varied depending on the gage that they were assigned to. There was nearly no confusion with respect to the procedure and no concern about the gage passing since they were not responsible for selecting the measuring instrument. However, the students did make a concerted effort to ensure that the gages were adjusted correctly and performing with minimal variation. Each student measured each part three times. Some gages had ten available parts to measure and some had only five. The students were required to input the data and write a brief report that analyzed how their gage performed with respect to the %EV, %AV and %RR.

Figure 2 - Sheffield air column

Activity 4

The final activity required students to work in teams to measure either the height or width of small cylinders which were approximately one inch tall by one-half inch in diameter and are shown in figure 3. This was done as the last class of the semester and the students were instructed to select any instrument that they felt was appropriate of all the instruments they were exposed to throughout the semester. The author desired that the students would select an instrument that would be capable to discriminate within one-tenth of the total part variation as no part tolerance was given. This did not occur. The author apparently did not make this criterion sufficiently known as judged by the resulting answers on a follow-up quiz. Each of the operators was to measure each of the ten parts three times. Each team was concerned that their selected

measuring instrument would successfully pass the gage analysis. Instruments selected included micrometers, calipers and a coordinate measuring machine. The teams had progressed to the point that they were actively honing the procedure used to measure the parts and were constantly refining their measurement technique.
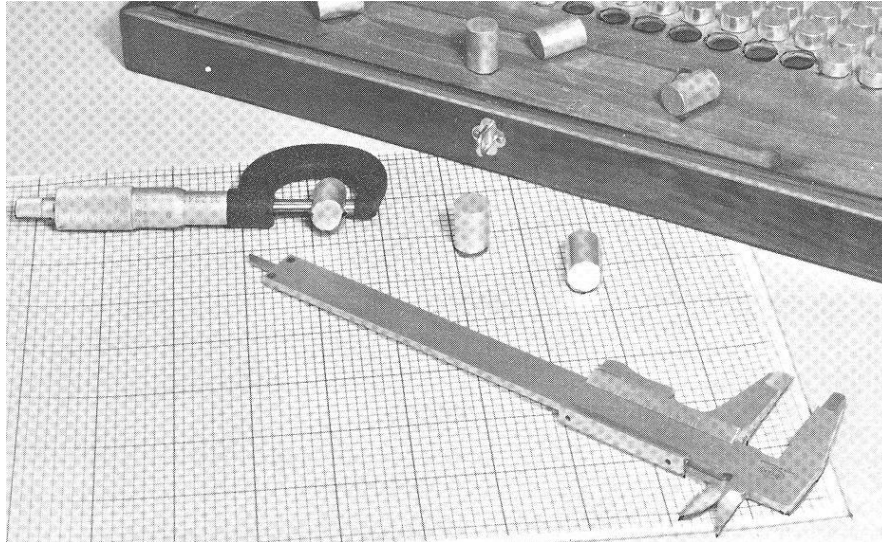

Figure 3 – Cylinders used in activity 4

Assessment

A survey was developed as an attempt to assess the value of the learning exercises. The survey was administered before and after activities 2, 3 and 4. The questions included in the assessment were answered on a 1 to 5 Likert scale from strongly agree to strongly disagree and are listed below:

1. A person will get the same result each time they measure a part with a certain instrument.
2. A measurement will not vary from operator to operator if they use the same measuring instrument.
3. The selection of an appropriate measuring instrument depends on the tolerance of the part
4. The selection of an appropriate measuring instrument depends on how much the parts vary.
5. I can select a measuring instrument to provide an adequate level of accuracy for an application.
6. I can determine the possible sources of measurement error in instrument use.

Additionally, a quiz was administered after activity four composed of the following questions:

1. What is the range of the measurement of the parts you are measuring?
2. What is an appropriate measuring instrument for this range? Explain your answer.
3. Why is it important for the operator to not know which part they are measuring?

4. Perform a Gage R and R with your selected instrument. Was your measuring instrument found to be acceptable by your Gage R and R? (Explain your answer)
5. Explain the results of your Gage R and R with respect to %EV, %AV etc. (What was the major source of reading variation? Within equipment? Operator to operator?) Also, address how your measuring system might be improved.

Assessment results

Results from the initial and final implementations of the survey are shown in figures 4 and 5 respectively. The majority of the change in results occurred between the pre-test and post-test of activity two. The survey was not administered before or immediately after activity one as it was yet to be created.
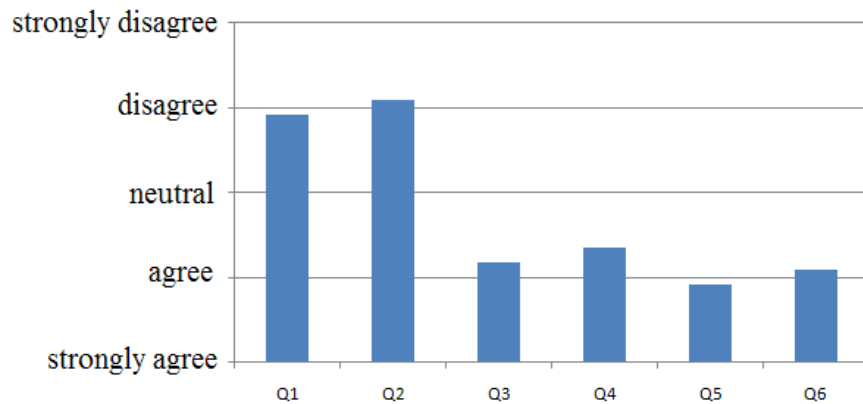
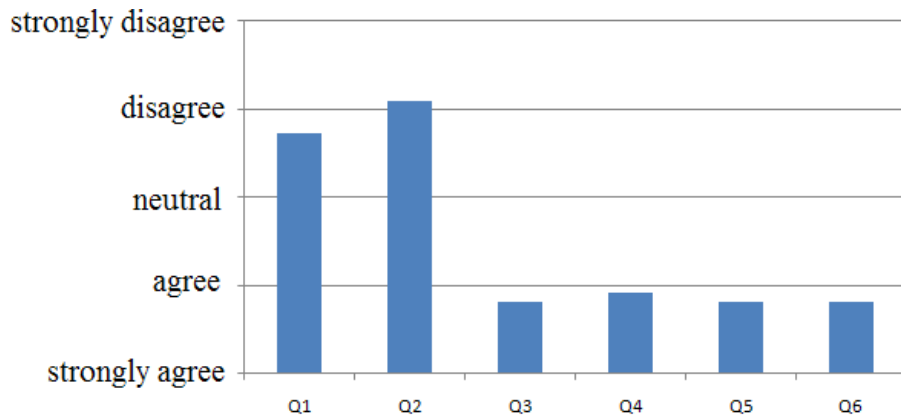

Figure 4 – Initial survey results (before activity two)

Figure 5 – Final survey results (after all four activities)

The first two questions could properly receive a "disagree" or "strongly disagree" answer and this was generally the case from the initial survey through the final survey. Question three could arguably be correctly answered as "agree", and this was the case both pre-test and post-test for

all the activities with some slight variation. The last three questions should receive a strongly agree answer, but they tended more towards agree. The greatest change in answer was to question four which moved towards the more correct answer of "strongly agree". Almost all of the movement for questions two through four was in a favorable fashion and occurred during the second activity. The results of the quiz administered after activity four were inconsistent and it is difficult to generalize beyond what has already been discussed.

Conclusions

The assessment instrument was found to be very poor at discriminating between the relative merits of the different activities. The author strongly feels that there was significant growth of the students' R&R knowledge and capabilities from activity to activity, but it is not apparent from the assessment tools that were used. Further development and refinement of the author's implemented assessment tools are required.

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