Construction and validation of a test of skills in farm mechanics for vocational agriculture pupils

Marvin D. Thompson
Iowa State College

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CONSTRUCTION AND VALIDATION OF A TEST OF SKILLS
IN FARM MECHANICS FOR VOCATIONAL AGRICULTURE PUPILS

by

Marvin D. Thompson

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Vocational Education

Approved:

In Charge of Major Work

Head of Major Department

Dean of Graduate College

Iowa State College

1955
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I. INTRODUCTION

Evaluation of pupil achievement is important in all fields of teaching. Teachers of farm mechanics and other shop teachers are frequently handicapped by a lack of procedures or devices to assist them in evaluation of products involving the application of manipulative skills.

Newkirk and Greene have made the following statement concerning the evaluation of shop projects and drawings:

The rating of shop projects and drawings is difficult; it requires a complex fusing of judgments based on a group of variable factors. Yet, psychologically, the rating of shop projects and drawings is little different from the rating of an English theme or a paper in mathematics. In English the factors to be considered may be spelling, punctuation, etc.; and in shop subjects the judgment may be based on such factors as tool processes, design, utility, finish, and fasteners. Teachers vary greatly in their concept of what constitutes perfection in a project or drawing. The same project or drawing looks different to different individuals, and quite probably to the same individual under different circumstances.

The present study is an attempt to develop various procedures of evaluation of some jobs in farm mechanics involving manipulative skills. Although this investigation is specifically concerned with but a few of the typical jobs in farm mechanics, the procedures used may suggest to the farm mechanics

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teacher, or other shop teacher, techniques and devices which may be used in the evaluation of similar jobs.

This study was limited to the development of sample test procedures for vocational agriculture pupils in farm mechanics, the evaluation of these procedures, and the revision of the test instruments to a workable form for use of teachers of vocational agriculture. Six test instruments were devised, each involving a job sheet and an evaluation technique for the resultant job product. Twenty-one teachers of vocational agriculture in Iowa participated in the investigation together with 918 pupils who constructed usable job products. The job products were independently evaluated by the high school vocational agriculture instructors and by three specialists in farm mechanics from the staff of the Department of Agricultural Engineering, Iowa State College.
II. REVIEW OF RELATED LITERATURE

A search of the available literature has shown little in the way of studies directed primarily toward the evaluation of skills in farm mechanics for vocational agriculture pupils. A number of authorities have stressed the importance of performance tests in evaluating the work of high school pupils in various areas of shopwork. Smith\(^1\) summarized the opinions of 70 college students, three-fourths of whom were experienced vocational teachers concerning pupil evaluation. These college students submitted items involved in pupil achievement and ranked the items with respect to their importance. The factors were ranked as follows:

1. Manipulation—product, workmanship, allied elements.
2. Knowledge—information, application, and planning.
3. Personal characteristics—attitudes and industriousness.

With another similar group of 87 college students Smith obtained weighted rankings in order to have comparative scores. This weighting was as follows:

Manipulation and the physical product—69 points.
Information, judgment, and planning ability—64 points.
Shop attitude and conduct—31 points.
Intelligence, appreciation, and initiative—21 points.

---
Newkirk and Greene developed project rating scales applicable to performance testing in farm mechanics or industrial arts. The authors suggested that a collection of representative specimens of varying merit be obtained and ranged in order of merit by means of the use of pooled judgments. Differences in quality could be established in terms of sigma units.

The United States Civil Service Commission developed a large number of tests of manipulative skills used in the selection of governmental employees. The typical scoring devices used involved the amount of time required to do the test job with penalties where the product failed to fall within the tolerances allowed.

Investigators at the University of Minnesota in the construction of the Minnesota Mechanical Ability Tests relied primarily on the time involved in assembling certain jobs in their determination of mechanical ability. A number of jobs involving manipulative skills were assembled and the scoring of the pupil was on a basis of the time to complete the assembly.

---

1 Newkirk and Greene, op. cit., p. 158.


A method of evaluating a unit in landscaping the home farm was suggested for pupils of vocational agriculture by Aderhold and Ekstrom\(^1\). These authors proposed techniques for evaluation in four areas: (1) information and technical terminology, (2) reasoning, (3) location of relevant data, and (h) skills. In the evaluation of the last named area, skills, pupils demonstrated their ability to set out trees and shrubs. Three elements were involved in each operation—quality, time, and sequence. A check list involving these elements was developed and a scoring system shown.

Point systems are often used by teachers in assigning grades in farm mechanics. McPhee\(^2\) reported that in 1932 about one-third of the vocational agriculture teachers in California were using some such system. More teachers were planning to do so the following year.

Slanger\(^3\) suggested a procedure for evaluating work in farm mechanics on a basis of quantity and quality. He listed projects in the various areas of farm mechanics with suggested points for

---


\(^2\)J. A. McPhee. California conference notes on the point system of grading farm mechanics. Agricultural Education. 5:72. November 1932.

\(^3\)B. S. Slanger. A plan for grading farm shop work. Agricultural Education. 8:106. January 1936.
quantity and also points for quality. Marks for pupils were then assigned on the basis of total points. He also suggested that a system of demerits be established for misdemeanors, incorrect use of tools, and similar situations.

Dolen and Schulz\(^1\) reported on the system developed in schools for army machinists. The authors stated that before the development of the system grades were highly subjective. One piece of work was resubmitted to the same instructor five times and was given five different grades ranging from 72 to 90 per cent.

The machine shop course reported upon consisted of twelve weeks of schooling with twelve weekly tests and thirty-two practical machine shop problems after which the trainees were classified as skilled, semi-skilled, helper, or non-graduate. Tolerances for the machine shop jobs were established and dimensions within these tolerances received perfect scores. In the case of a product beyond these tolerances five percentage points were deducted for each 0.001" from the tolerance. Job sheets listed the tolerance for each dimension. A maximum time was allowed for each job according to its difficulty and one inspector handled all the grading for about 90 men. The authors felt that this system was accurate, objective, and easily administered.

Edees. Indirect antice and Vocational Education. "June 1945."* 1a. 

In the determimnation of retaile edaides, in the one or ote of factors. Quantity determinates become evident in the relatiwe welfare of these that were eaten and daily diterred in the market to scores of scores. Write a note to these in these diterred in the retaile scores of retaile edaides. 

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In the retaile edaides. 

In the retaile edaides.

* The authors reported on the problems involved in ascertaining the retaile edaides. 

* The retaile edaides must be tested for retaile edaides. 

* The typical methods of retaile edaides are not necessarily standardized. Retaile edaides may be established. 

* Retaile edaides on shop performance are frequently worthless. 

conclusions:

They came to the following...
determination of maximum points on a scoring curve, and in
the assignment of weights to various factors.

Some improvements in the instruction and evaluation in
a naval training course in aircraft welding were reported
by LaTondresse. He cited as a need for improvement in
evaluation the following:

1. Unfair marks gave students no incentive to learn.
2. Accuracy was needed since top ranking students
were advanced in grade.
3. During the war emergency it was important that
personnel, rated to perform certain operations,
could actually do so.

Before revision of the testing procedure, each instructor
evaluated 20 welding samples. The mean scores of the two
instructors at the extremes in rating were 75.75 and 87.65
per cent with a coefficient of correlation of 0.941.

Scoring factors with relative weights were determined
to be smoothness of bead—2, width of bead—2, height of
bead—2, penetration with fusion—6, condition of ends—2,
fusion of edges—3, and preparation of weld—2. The specimen
was rated on each factor as average(0), above average (+1),

\(^1\)W. R. LaTondresse. A grading plan for welding. Un-
published M. S. Thesis, Menomonie, Wisconsin, The Stout
Institute Library, 1947.
or below average (-1); the rating was multiplied by the weight of the factor and added algebraically to a mean score of 80. This could give a range in scores from 61 to 99 per cent. When this system was used the instructors at extremes of disagreement had mean scores of 78.80 and 81.35 with a coefficient of correlation of 0.717.

A further step included a quality rating scale with specimen welds. Whereas mean scores of the instructors at the extremes were 81.60 and 76.60, the coefficient of correlation was 0.969 indicating consistent differences in the level of scoring.

Gerber\(^1\) reported on the construction of a test in orthographic projection which included 81 items. The test measured the ability of the pupil to interpret drawings and to complete figures. Technique in drawing was not involved and the items were arranged in increasing difficulty. The test was used with 7th through 12th grade pupils and appeared to work satisfactorily with all grades.

McPherson\(^2\) described the use of model wood block pattern using saw, drill, and chisel to test shop performance. The


product was scored with respect to accuracy of dimensions, angles, and locations. A scoring pattern was developed on a plastic material and deviation lines were drawn at uniform intervals to indicate the degrees of deviation of the product from the model. One point was deducted from a perfect score of 10 for each unit of deviation. Raw scores were multiplied by certain numbers ranging from 1 to 6 depending upon the difficulty of the task.

An example of a practical type of woodworking test was described by Fenn. He used a test object which incorporated a large number of woodworking operations and as a means of scoring divided the operations into quality points:

1. Squaring stock to dimensions— 30 points
2. Chiseling convex curve— 10 points
3. Sawing corner— 5 points
4. Chamfering corner— 5 points
5. Chamfering end— 10 points
6. Boring hole— 5 points
7. Cutting with gouge— 15 points
8. Chiseling across grain for dado— 20 points

Total 100 points

Fenn did not list any particular standards for workmanship.

---

Some vocational instructors use a system of evaluation similar to that reported by Dickey\textsuperscript{1}. He used a rating scale for each of his machine shop jobs. If, for example, there were eight measurements for a job and the pupil had all measurements within these tolerances, he received an A mark; if seven, then a B mark. When the rating was four or below, the job would be remade. Dickey used a student inspector from an advanced class to do all checking. This student maintained a set of tools and gauges for that job and filled out inspection reports on the work.

Hunter\textsuperscript{2} described a system whereby the vocational shop teacher could incorporate the use of time in a testing situation for machine shop pupils. The test job was similar to a project given in first-year machine shop practice. It was a bench job and involved hack sawing, layout, filing to a line, measuring with a micrometer, filing and fitting to radius gauges, and draw filing for finish.

Points were given for accuracy in thickness measurement, for scalar dimensions, and for radius measurements. Time was

\textsuperscript{1}F. M. Dickey. Inspecting machine work in a general shop Industrial Arts and Vocational Education. 35:304-305. September 1946.

recorded and an average of all time computed. A value was determined by the formula

\[ E = P \times P \times Sq \]

where

- \( E \) = pupil efficiency as measured by accuracy, speed, and finish for a job.
- \( P \) = total points for accuracy and finish.
- \( Sq \) = speed quotient as per cent of time greater or less than the average time.

Hunter cited as advantages of this system the following:
1. The slow but accurate worker was not jeopardized.
2. The test tended to eliminate the slow and inaccurate worker.
3. The test placed pupils under pressure and thus tended to simulate industrial conditions.
4. The test made the pupil more conscious of speed.
5. Test results tended to follow a curve of normal distribution.
6. The test appeared to be objective in form.

One of the main disadvantages of the test, according to Hunter, was the extensive amount of time necessary to take the test.
III. METHOD OF PROCEDURE

The present investigation was confined to the development of sample test procedures for vocational agriculture pupils in farm mechanics, the evaluation of these procedures, and the revision of the test instruments to a workable form for use of teachers of vocational agriculture.

Sample jobs in various areas of farm mechanics involving simple skills were selected as presenting typical evaluation problems. Job sheets were developed giving the accepted procedure for doing each job. The test instruments were then developed.

The plans for the study were discussed with H. T. Hall, Supervisor of Agricultural Education in Iowa. He approved the use of the test instruments in a number of departments of vocational agriculture in the state. Arrangements were then made with 21 vocational agriculture instructors to participate in the testing program.

Construction materials used in the test as well as job and evaluation sheets were supplied by the author. The local instructor gave the tests and evaluated them by use of the rating instruments. Relevant data such as grade level, previous mark in farm mechanics, I. Q. scores, and time involved in completion of the job were recorded for each pupil, insofar as the data were available.
The job products were then evaluated independently by three members of the staff of the Department of Agricultural Engineering of Iowa State College using the same system as that used by the local vocational agriculture instructor.

An analysis of covariance was computed from the scores given each job to determine if any significant differences existed in the scoring by the evaluators or in the quality of job products by pupils of different class levels. The within alone regression equations from the analyses of covariance were used to provide a weighting system which showed the extent to which factors included in the original test instruments contributed to the evaluation of the quality of the job products.
IV. DEVELOPMENT OF TEST MATERIALS

Much of the work in farm mechanics taught to vocational agriculture pupils is in the form of simple manipulative skills. In order to be useful for this evaluative scheme the skills tested had to meet certain criteria: each skill selected had to be one commonly taught to all farm mechanics pupils; and each skill had to be one that could be completed in a reasonable period of time. In the case of each skill the job product had to be one which would be readily portable, and which was relatively inexpensive. It was also felt to be advisable to include jobs in as many different areas of farm mechanics as possible.

With the above criteria in mind, six jobs were selected as suitable for use. They were:

1. Making a framing square hanger which primarily involved the skills of layout and sawing with a hand saw.

2. Making a funnel pattern which involved the skills of reading a drawing and making a layout from that information.

3. Turning an eye for an eyebolt which involved the skill of shaping hot metal.

4. Cutting threads for the eyebolt which involved skill in using thread cutting equipment.
5. Making a butt weld which involved preparation of the metal and welding in the flat position.

6. Replacing a ledger plate on a mower guard which involved skills in the removal of the old ledger plate and in the placement and riveting of a new ledger plate.¹

The job sheets were prepared in order to give consistent directions to the pupils involved in the testing and to suggest that each pupil use a similar procedure in doing each job. Insofar as possible the directions given in the job sheets involved procedures recommended by authors of farm mechanics texts. Texts used for this purpose were by Cook, Scranton, and McColy;² Jones³; and Morford⁴.

¹See Appendix for job sheets and pictures of job products. p. 52-69.


In the development of the evaluation sheets¹ an attempt was made to use equipment or tools which were readily available to the vocational agriculture teacher. An effort was also made to use measurements or gauge readings which could be made easily and quickly.

Samples of the job products involving the skills to be tested were studied to determine the errors generally made by pupils in the construction of the projects. It appeared possible to evaluate some job products entirely by gauges or scales, whereas others necessarily had to be evaluated somewhat subjectively. There were two basic types of evaluation techniques. One involved a system of measurement using scales or gauges to determine variations in dimensions, and the other involved a subjective evaluation in the form of choosing an appropriate number on a descriptive scale.

The gauges finally used were in the form of measured deviations from the correct pattern or shape. It was assumed that the greater number of units of deviation indicated a poorer quality of work in that particular respect. The descriptive scales were also set up in the same manner in order that a poorer quality of work would be indicated by a larger number on the scale. Descriptive statements, phrases, or words were included with the scale to facilitate the marking

¹See Appendix for evaluation sheets, p. 70-74.
of the proper quality rating. The evaluative instruments were checked and revised by using them to score similar projects made by students in two courses at Iowa State College; namely, Agricultural Engineering 254, Farm Mechanics; and Agricultural Engineering 255, Farm Carpentry.
V. ADMINISTRATION OF TEST MATERIALS

As a result of personal interviews with a number of teachers of vocational agriculture concerning their interest in the proposed study, twenty-one teachers were selected who were willing to cooperate by giving the tests and evaluating the results. No attempt was made to select only those teachers with good shop facilities or those with outstanding shop programs. The teachers were located in various areas of the state. The cooperating departments were Adel, Ankeny, Belmond, Fort Dodge, Grinnell, Humbeston, Iowa Falls, Manson, Marion, New Virginia, Orange Township, Oskaloosa, Radcliffe, Reinbeck, Rolfe, Spencer, Stanhope, Story City, Stratford, Waukee, and West Liberty.

Supplies for the jobs which were provided by the author consisted of wood for the sawing job; paper for the funnel layout job; a length of round mild steel and a nut for the eyebolt and threadcutting jobs; metal for the welding job; and rivets, ledger plates, mower guards, and punches for the ledger plate replacement job.

These supplies were delivered to the schools by the author with a data sheet, job sheets, and evaluation sheets. After completion of the work by the pupils and evaluation by the teacher, another visit was made to each school in order to secure the completed test materials.
The local vocational agriculture teacher selected for testing pupils in classes in which previous instruction had been given in the skills to be tested. The tests were administered in April and May, 1953. No attempt was made to test pupils in certain classes with all tests since this would have involved a large amount of time on the part of the teacher.

An attempt was made to follow a definite procedure in the administration of the tests. The pupils were informed that the tests were being given in order to determine the quality of work which pupils do on jobs of this sort. The pupils were asked to read the job sheet carefully so that there would be no difficulty in following the procedure as outlined. Each pupil had available his material and tools before starting work. The time involved in doing the job was recorded.

The vocational agriculture teacher then evaluated the job products as suggested in the evaluation sheet. On the data sheet he recorded the I. Q. score of the pupil, the class level of the pupil, and the previous mark of the pupil in farm mechanics if this information was available.

The job products were independently evaluated by three farm mechanics specialists using the same evaluation techniques as those used by the vocational agriculture teacher. Each of the three evaluators had had previous experience in farm mechanics work with high school pupils as well as with college students.
VI. ANALYSIS OF TEST MATERIALS

In an attempt to determine the effectiveness of the evaluative instruments an analysis of covariance for scores given in five of the six jobs was computed. The sixth job, removing and replacing a ledger plate, was not treated due to the lack of a sufficient number of cases. To establish a prediction formula the various factors involved in the over-all rating were used as prediction variables and the over-all rating was used as the criterion. Controls were made on the evaluators of the job product and on the class level of the pupils.

A multiple coefficient of correlation of 0.8153 was computed for the scores given to job products in job 1, making a framing square hanger. The F-value of 14.83, shown in Table 1, indicated that highly significant differences existed between the scores given by evaluators on this job. The mean scores\(^1\) for job 1 are given in Table 2. These mean scores show that the local agricultural instructor, evaluator I, placed a higher quality rating on the job products than did any of the other three evaluators.

\(^1\) A higher mean score in these tables indicates a product of lower quality than those receiving low mean scores. The scoring was on a basis of a scale in which 1 = excellent quality of job product and 5 = unsatisfactory job product.
Table 1

Analysis of covariance for job 1, making a framing square hanger

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
<th>Sum of squares</th>
<th>Mean square</th>
<th>F² value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluator</td>
<td>3</td>
<td>13.3158</td>
<td>4.4386</td>
<td>14.83**</td>
</tr>
<tr>
<td>Class</td>
<td>3</td>
<td>1.7837</td>
<td>0.5946</td>
<td>1.99</td>
</tr>
<tr>
<td>Interaction</td>
<td>9</td>
<td>2.7261</td>
<td>0.3032</td>
<td>1.01</td>
</tr>
<tr>
<td>Within</td>
<td>765</td>
<td>228.9833</td>
<td>0.2993</td>
<td></td>
</tr>
</tbody>
</table>

*Asterisks following F-values are statistical symbols that have the following meaning:
No asterisk means that the value is not significant.
One asterisk (*) means that the value is significant at the 5% level.
Two asterisks (**) mean that the value is significant at the 1% level.
The scoring was on a scale of 6 with 5 = unmet and 6 = met. The scores for each observer were averaged. The observers were.

<table>
<thead>
<tr>
<th></th>
<th>1.753</th>
<th>3.753</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer I</td>
<td>3.9078</td>
<td>3.2867</td>
<td>Observer II</td>
</tr>
<tr>
<td>Observer III</td>
<td>3.7356</td>
<td>1.9050</td>
<td>Observer III</td>
</tr>
<tr>
<td>Observer II</td>
<td>3.9645</td>
<td>1.9050</td>
<td>Observer I</td>
</tr>
<tr>
<td>Observer I</td>
<td>3.5567</td>
<td>1.9048</td>
<td>Adjusted I</td>
</tr>
</tbody>
</table>

A treatment square has been scored by evaluating for Job 1, meeting the standards by evaluating for Job 1, meeting the standards.

Table 2
With the scores from job 2, making a funnel pattern, a multiple coefficient of correlation of 0.7529 was shown to exist. The analysis of covariance for the scores on this job showed highly significant differences between evaluators and between class levels in the quality of the final job product. The F-values for the analysis of covariance are shown in Table 3. The adjusted mean score of 2.8089, shown in Table 4, indicated that evaluator III believed the job products to be of better quality than did any of the other evaluators. Senior class members appeared to be more proficient than members of other classes in their ability to do the manipulative skills in laying out the funnel pattern from a drawing.

A multiple coefficient of correlation of 0.7474 was found for scores from job 3 which consisted of turning an eye for an eyebolt. The F-values, shown in Table 5, indicated that highly significant differences existed between the evaluators in the scores given the job products, between the class levels of the pupils tested, and in the interaction of these two controls. The adjusted mean score of 2.7207, shown in Table 6, indicated that the local instructor, evaluator I, rated the quality of product higher than did any of the other evaluators. Pupils in the freshman class produced a poorer job product than did pupils at other class levels. A probable reason for the highly
significant interaction might be that local instructors may have a tendency to expect varying standards of workmanship for pupils at different class levels.
Table 3

Analysis of covariance for job 2, making a funnel pattern

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
<th>Residuals</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sum of squares</td>
<td>Mean square</td>
</tr>
<tr>
<td>Evaluator</td>
<td>3</td>
<td>33.8824</td>
<td>11.2941</td>
</tr>
<tr>
<td>Class</td>
<td>3</td>
<td>12.6242</td>
<td>11.2081</td>
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<tr>
<td>Interaction</td>
<td>9</td>
<td>4.0570</td>
<td>0.4508</td>
</tr>
<tr>
<td>Within</td>
<td>719</td>
<td>631.9112</td>
<td>0.8789</td>
</tr>
<tr>
<td></td>
<td>3.1287</td>
<td>3.1287</td>
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</tr>
<tr>
<td>----------</td>
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<td>--------</td>
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</tr>
<tr>
<td>Senator</td>
<td>2.941</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junior</td>
<td>3.009</td>
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</tr>
<tr>
<td>Sophomore</td>
<td>3.856</td>
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<tr>
<td>Freshman</td>
<td>3.333</td>
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</tr>
<tr>
<td></td>
<td>3.291</td>
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<tr>
<td></td>
<td>3.355</td>
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<td></td>
<td>3.807</td>
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</tr>
<tr>
<td></td>
<td>3.195</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.179</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Wich is a matrix pattern

Mean scores by evaluator and class for job 2

Table 1
Table 5

Analysis of covariance for job 3,
turning an eye

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
<th>Residuals</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sum of squares</td>
<td>Mean square</td>
<td>F</td>
<td>value</td>
</tr>
<tr>
<td>Evaluator</td>
<td>3</td>
<td>48.2197</td>
<td>16.0632</td>
<td>42.82**</td>
<td></td>
</tr>
<tr>
<td>Class</td>
<td>3</td>
<td>16.3542</td>
<td>5.4514</td>
<td>14.51**</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>9</td>
<td>20.7392</td>
<td>2.3044</td>
<td>6.14**</td>
<td></td>
</tr>
<tr>
<td>Within</td>
<td>680</td>
<td>255.4010</td>
<td>0.3756</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 6

Mean scores by evaluator and class for job 3,

*turning an eye*

<table>
<thead>
<tr>
<th>Evaluator</th>
<th>Y</th>
<th>Adjusted Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2.8743</td>
<td>2.7207</td>
</tr>
<tr>
<td>II</td>
<td>3.0343</td>
<td>2.9377</td>
</tr>
<tr>
<td>III</td>
<td>3.3429</td>
<td>3.4731</td>
</tr>
<tr>
<td>IV</td>
<td>3.2286</td>
<td>3.3486</td>
</tr>
<tr>
<td>Freshman</td>
<td>3.9444</td>
<td>3.7482</td>
</tr>
<tr>
<td>Sophomore</td>
<td>3.1027</td>
<td>3.0511</td>
</tr>
<tr>
<td>Junior</td>
<td>3.0159</td>
<td>3.0696</td>
</tr>
<tr>
<td>Senior</td>
<td>3.1223</td>
<td>3.1626</td>
</tr>
<tr>
<td>Total</td>
<td>3.1200</td>
<td>3.1200</td>
</tr>
</tbody>
</table>
From the scores on job 4, cutting threads, a multiple coefficient of correlation of 0.8652 was shown to exist between the various quality checks and the over-all evaluation. As shown in Table 7, highly significant differences existed between evaluators and between class levels in the scores assigned to the quality of the work produced. These differences were similar to differences found in some of the jobs previously discussed. As shown by the adjusted mean scores in Table 8, evaluator I did not score as critically as other evaluators, and freshman class members appeared to do a poorer quality of work than members of other classes.

Job 5 consisted of making a butt weld. A multiple coefficient of correlation of 0.9502 was shown to exist between the scores assigned to this job. The F-values of 33.49 for evaluator and 1.14 for interaction were highly significant. The F-value for class level approached significance at the 5% level. These F-values are shown in Table 9. The adjusted mean scores, shown in Table 10, showed that evaluator I scored the quality of the welding jobs somewhat higher than other evaluators and that evaluator III was more critical of the job quality than the other evaluators. The highly significant interaction may have been due to a tendency for the vocational agriculture instructor, evaluator I, to have varying standards of quality for pupils in different class levels. Thus the
instructor may have assigned a poorer quality rating to the job product of a senior pupil even though the job product was similar to that of a freshman pupil.

No attempt was made to use time involved in constructing the job product as a variable in determining the score for the job produced. There appeared to be no real agreement among specialists in testing regarding the importance of this factor. It was decided that the local instructor should determine whether some emphasis should be given to the amount of time required to complete the job product.

It was beyond the scope of this study to determine whether relationships existed between the I. Q. scores of pupils or their previous marks in farm mechanics and the scores on their job products.
Table 7

Analysis of covariance for job b,
cutting threads

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
<th>Residuals</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sum of</td>
<td>Mean</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>squares</td>
<td>square</td>
<td>value</td>
</tr>
<tr>
<td>Evaluator</td>
<td>3</td>
<td>11.7443</td>
<td>3.9148</td>
<td>11.24**</td>
</tr>
<tr>
<td>Class</td>
<td>3</td>
<td>5.7801</td>
<td>1.9267</td>
<td>5.53**</td>
</tr>
<tr>
<td>Interaction</td>
<td>9</td>
<td>5.1899</td>
<td>0.5767</td>
<td>1.66</td>
</tr>
<tr>
<td>Within</td>
<td>669</td>
<td>232.9211</td>
<td>0.3482</td>
<td></td>
</tr>
</tbody>
</table>
Table 8

Mean scores by evaluator and class for job 4, cutting threads

<table>
<thead>
<tr>
<th></th>
<th>Y</th>
<th>Adjusted Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluator I</td>
<td>2.6337</td>
<td>2.7891</td>
</tr>
<tr>
<td>Evaluator II</td>
<td>2.9535</td>
<td>3.1419</td>
</tr>
<tr>
<td>Evaluator III</td>
<td>3.2093</td>
<td>3.0612</td>
</tr>
<tr>
<td>Evaluator IV</td>
<td>3.2093</td>
<td>3.0135</td>
</tr>
<tr>
<td>Freshman</td>
<td>3.8889</td>
<td>3.2084</td>
</tr>
<tr>
<td>Sophomore</td>
<td>2.9952</td>
<td>3.0932</td>
</tr>
<tr>
<td>Junior</td>
<td>2.8750</td>
<td>2.9831</td>
</tr>
<tr>
<td>Senior</td>
<td>3.0106</td>
<td>3.1021</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3.0015</strong></td>
<td><strong>3.0015</strong></td>
</tr>
</tbody>
</table>
Table 9

Analysis of covariance for job 5, making a butt weld

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
<th>Residuals</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sum of squares</td>
<td>Mean square</td>
<td>F value</td>
<td></td>
</tr>
<tr>
<td>Evaluator</td>
<td>3</td>
<td>10.5536</td>
<td>3.5179</td>
<td>33.49**</td>
<td></td>
</tr>
<tr>
<td>Class</td>
<td>3</td>
<td>0.7452</td>
<td>0.2484</td>
<td>2.36</td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>9</td>
<td>3.9137</td>
<td>0.4349</td>
<td>4.14**</td>
<td></td>
</tr>
<tr>
<td>Within</td>
<td>727</td>
<td>76.3601</td>
<td>0.1050</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 10

Mean scores by evaluator for job 5, making a butt weld

<table>
<thead>
<tr>
<th>Evaluator</th>
<th>$\bar{y}$</th>
<th>Adjusted $\bar{y}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluator I</td>
<td>3.4011</td>
<td>3.8060</td>
</tr>
<tr>
<td>Evaluator II</td>
<td>4.1176</td>
<td>3.9269</td>
</tr>
<tr>
<td>Evaluator III</td>
<td>4.2941</td>
<td>4.1559</td>
</tr>
<tr>
<td>Evaluator IV</td>
<td>3.9358</td>
<td>3.8608</td>
</tr>
<tr>
<td>Total</td>
<td>3.9372</td>
<td>3.9372</td>
</tr>
</tbody>
</table>
VII. REVISION OF TEST MATERIALS

There was an obvious need to revise the instruments in order to obtain a form more usable by a vocational agriculture instructor. This revision involved two steps, namely the deletion of factors found to be relatively unimportant in achieving a score and the weighting of the factors in terms of their relative value.

The contribution of each prediction factor to the sum of squares of residuals in the within equation was examined, and where necessary variables were dropped to test for the significance of the loss in predictive value. The deviation form of the within equation was used and the standard deviation of each factor multiplied by its proper coefficient. This gave a comparative weighting of each factor contributing to the total score. These values were adjusted and rounded to the nearest digit to give a simple predictive scheme.

In revising the scoring technique for job 1, the within regression equation for the scores for that job was found to be

\[ y = 0.056918351x_1 + 0.04055347x_2 + 0.59923552x_3 \]

where, in deviation form

\[ y = \text{over-all estimate of the quality of the completed job} \]
$x_1 =$ number of deviations from check points

$x_2 =$ number of deviations in angle of sawing

$x_3 =$ smoothness value

From the general form for sums of squares of residuals

\[ \text{S. S. of residuals} = \sum y^2 - (a_1 x_1 y + a_2 x_2 y + a_3 x_3 y) \]

the values were found to be

\[ \text{S. S. of residuals} = 682.890 - (82.07911 + 52.5230 + 319.28527) = 228.98332 \]

Each of these values appears to make a definite contribution to the sums of squares of residuals for within values and thus each was retained in the predictive scheme.

The standard deviations for the prediction variables were found to be

\[
x_1 = 4.586 \\
x_2 = 4.60 \\
x_3 = 1.00
\]

The standard deviations were multiplied by their corresponding values in the regression equation previously shown. The following weighted equation was obtained:

\[ y = 0.26102733x_1 + 0.18654598x_2 + 0.59923552x_3 \]

To obtain a simple predictive scheme these values were adjusted and rounded. The scoring scheme for evaluating the framing square hanger product was developed as follows:
Deviations from check points X 3 = __________

Deviations in sawing angle X 2 = __________

Smoothness value X 6 = __________

Total score for job 1 = __________

The within regression equation for the scores for job 2, making a funnel pattern, was found to be

\[ y = 0.1139748x \]

where, in deviation form

\[ y = \text{over-all estimate of the quality of the completed job} \]
\[ x = \text{number of deviations from check points} \]

The standard deviation for the prediction variable \( x \) was found to be 9.30. This value when multiplied by the coefficient of \( x \) gave a prediction equation as follows:

\[ Y = 1.06007999x \]

To obtain a simple prediction scheme this number was adjusted and rounded and the evaluation of the funnel layout job was changed to be

Deviations from check points X 10 = __________

Total score for job 2 = __________
The scores for job 3, turning an eye for an eyebolt, produced a within regression equation as follows:

\[ y = 0.1269009907x_1 + 0.2117870107x_2 + 0.3035187447x_3 + 0.2509369180x_4 \]

where, in deviation form

\[ y = \text{over-all estimate of the quality of the completed job} \]

\[ x_1 = \text{number of deviations from gauge} \]

\[ x_2 = \text{number of deviations from flat surface} \]

\[ x_3 = \text{score on prevalence of hammer marks} \]

\[ x_4 = \text{score on degree to which metal was burnt} \]

From the general form for sums of squares of residuals

\[ \text{S. S. of residuals} = \Sigma y^2 - (a_1 \Sigma x_1 y + a_2 \Sigma x_2 y + a_3 \Sigma x_3 y + a_4 \Sigma x_4 y) \]

the values were found to be

\[ \text{S. S. of residuals} = 578.65648 - (117.07854 + 35.36291 + 99.29577 + 71.51830) = 255.40096 \]

Examination of these values showed that each factor made a definite contribution to the predictive scheme.

The standard deviations for the prediction variables were found to be

\[ x_1 = 2.842 \]

\[ x_2 = 0.769 \]

\[ x_3 = 0.971 \]

\[ x_4 = 0.976 \]
The standard deviation values were multiplied by the coefficients in the regression equation previously given and the following equation obtained:

\[ Y = 0.3606526X_1 + 0.1629277X_2 + 0.294747X_3 + 0.2450399X_4 \]

These values were founded and the scoring device for evaluating the eyebolt was

\[
\begin{align*}
\text{Deviations from gauge} & & X_4 = \_\_\_\_ \\
\text{Deviations from flat surface} & & X_2 = \_\_\_\_ \\
\text{Score on hammer marking} & & X_3 = \_\_\_\_ \\
\text{Score on degree of burnt metal} & & X_3 = \_\_\_\_ \\
\text{Total score for job} 3 & = \_\_\_\_ 
\end{align*}
\]
The within-job scores for Job 7, squaring the differences, the within

\[ \varepsilon_{\text{within}} = 0.04956904 + 2 \times 0.00933386 \times 0.02797995 \]

Therefore, a new regression equation could be used to estimate the value of the \( Y \) score in the absence of the value estimated upon examination of these values, it appeared that there was significant evidence of a correlation between the \( Y \) score and the 

\[ S.5 \text{ of residuals} = 0.5557 \text{ of residuals} = 0.5557 + 0.9768 \]

\[ (\varepsilon_{\text{within}} + \varepsilon_{\text{within}} + \varepsilon_{\text{within}}) = \varepsilon_{\text{within}} \]

from the general form for some of squares of residuals

\[ \text{score} = \varepsilon_{\text{within}} \text{ of residuals} \]

\[ \text{number of students} \times 2 \times 2 \]

\[ \text{number of students from subgroup} \times \text{number of students from subgroup} \]

\[ \text{within-job scores for Job 7, squaring the differences, the within} \]

\[ \varepsilon_{\text{within}} = 0.04956904 + 2 \times 0.00933386 \times 0.02797995 \]

Therefore, a new regression equation could be used to estimate the value of the \( Y \) score in the absence of the value estimated upon examination of these values, it appeared that there was significant evidence of a correlation between the \( Y \) score and the
Table 11

Loss due to elimination of deviations from length

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
<th>Sum of squares</th>
<th>Mean square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three variable regression</td>
<td>3</td>
<td>693.6306</td>
<td></td>
</tr>
<tr>
<td>Two variable regression</td>
<td>2</td>
<td>689.0080</td>
<td></td>
</tr>
<tr>
<td>Loss due to elimination of length deviations</td>
<td>1</td>
<td>4.6226</td>
<td>4.6226</td>
</tr>
<tr>
<td>Three variable residuals</td>
<td>684</td>
<td>232.9211</td>
<td>0.3405</td>
</tr>
<tr>
<td>Total</td>
<td>687</td>
<td>926.5517</td>
<td></td>
</tr>
</tbody>
</table>

\[ F_{1,684} = 13.57^{**} \]
The standard deviations for the three variables were

\[ X_1 = 1.465 \]
\[ X_2 = 3.562 \]
\[ X_3 = 1.285 \]

which, when multiplied by the values in the regression equation
gave the equation as follows:

\[ Y = 0.0825769X_1 + 0.6482753X_2 + 0.7459275X_3 \]

To obtain a simple prediction scheme the weighted values
for the various factors in evaluating the quality of the
thread cutting job were

<table>
<thead>
<tr>
<th>Score on fit of threads</th>
<th>( X_8 ) =</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviations from length</td>
<td>( X_1 ) =</td>
</tr>
<tr>
<td>Number of chip marks</td>
<td>( X_5 ) =</td>
</tr>
</tbody>
</table>

Total score for job 4 =
In evaluating the scores for job 5, making a butt weld, the
within regression equation was found to be

\[ y = 0.27003995x_1 + 0.01369346x_2 + 0.013037296x_3 \\
+ 0.35066167x_4 + 0.33949437x_5 \]

where, in deviation form

\[ y = \text{over-all estimate of the completed weld job} \]
\[ x_1 = \text{score on general appearance of the weld} \]
\[ x_2 = \text{score on amount of slag inclusions} \]
\[ x_3 = \text{score on degree of undercutting} \]
\[ x_4 = \text{score on strength of weld} \]
\[ x_5 = \text{score on depth of penetration} \]

From the general form for sums of squares of residuals

S. S. of residuals = \[ \Sigma y^2 = (a_x^2x_1y + a_y^2x_2y + a_z^2x_3y + a_4^2x_4y + a_5^2x_5y) \]

the following values were found:

S. S. of residuals = 786.3937 = (182.127h3 - 7.085h6 + 0.46612 \\
+ 268.61803 + 266.83976) = 76.36006

Of these values the contribution of \( x_2 \) and \( x_3 \) were negligible
and were not used in the final prediction form.

The standard deviations for the three remaining variables were

\[ x_1 = 1.165 \]
\[ x_4 = 1.125 \]
\[ x_5 = 1.174 \]
These values when multiplied by their respective coefficients gave the equation as follows:

\[ Y = 0.314586109X_1 + 0.394494379X_4 + 0.39856639X_5 \]

The prediction scheme for the weld job therefore became

<table>
<thead>
<tr>
<th>Score on general appearance</th>
<th>( \times 3 = )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score on strength of weld</td>
<td>( \times 4 = )</td>
</tr>
<tr>
<td>Score on penetration of weld</td>
<td>( \times 4 = )</td>
</tr>
</tbody>
</table>

Total score for job 5 =
VIII. SUMMARY

This investigation involved an attempt to develop sample test procedures of manipulative skills for vocational agriculture pupils in farm mechanics, to evaluate these procedures, and to revise the test instruments to a workable form for use by teachers of vocational agriculture.

Sample jobs involving simple skills in farm mechanics were selected as presenting typical evaluation problems. Job sheets and evaluative instruments were developed. Jobs selected as suitable for use in the testing program were:

1. Making a framing square hanger.
2. Making a funnel pattern.
3. Turning an eye for an eyebolt.
4. Cutting threads.
5. Making a butt weld.
6. Replacing a ledger plate.

Directions given in the job sheets were similar to those recommended by authors of farm mechanics texts. The evaluative techniques consisted of two types. One involved a system of measurement using scales or gauges to determine variations in dimensions, and the other involved a subjective evaluation in the form of choosing an appropriate number on five-point descriptive scales to indicate variations in quality.
Twenty-one teachers of vocational agriculture from departments located in various areas in Iowa participated in the study. The tests were given to pupils in classes having received some previous instruction in the skills to be tested. Usable job products were obtained from 918 pupils. Each job product received four evaluations. One evaluation was by the local vocational agriculture teacher and three were by teachers of farm mechanics on the staff of the Department of Agricultural Engineering of Iowa State College with previous experience in teaching farm mechanics to high school pupils.

A multiple coefficient of correlation was obtained for each of five jobs for which sufficient data were available. The correlations were between scores on the various factors involved in the instruments and the over-all ratings. These correlations were: 0.8153 for making the framing square hanger, 0.7529 for making a funnel pattern, 0.7474 for turning an eye for an eyebolt, 0.8652 for cutting threads, and 0.9502 for making a butt weld.

An analysis of covariance for scores given in each of the aforementioned five jobs was computed. Controls were made on the evaluators of the job products and on the class levels of the pupils tested. In each of the five jobs highly significant differences were found between the scores given by evaluators for the quality of the job products. In four
which are taught in farm mechanics or in other shop courses.

Such courses are taught in order to prepare students for evaluating other skills. The study should

This investigation was described in a paper distributed by the Vocational Education Institute.

The tests were administered in order to obtain

e a simple scoring scheme.

and weights were determined for each variable in order to obtain

were dropped which made no contribution to the score of the

From usable data the Vocational Education Institute

The tests were administered in order to obtain a

certain number of scores.

are junior and senior pupils in the vocational job shop products. In general, teachers and employers and superiors were not as

the quality of the completed job product. Repeated and scores for the quality of the completed job product. Differences exist between the classes listed in the table. When three of the five jobs tested there were significant

classes.

their evaluations of the quality of work performed in college

classes in farm mechanics have been influential in

The three evaluators who had recent experience in teaching

results on the job product than did the other three evaluators.

the local agricultural instructors. A better guarantee

of the five jobs these differences were due to the fact that
IX. REFERENCES


Dickey, F. M. Inspecting machine work in the general shop. Industrial Arts and Vocational Education. 35:304-305. 1946.

Dolan, F. D. and Schulz, H. A. Machine shop grading in the ordnance school. Industrial Arts and Vocational Education. 43:303-305. 1944.

Fenn, I. M. A practical woodwork test. Industrial Arts and Vocational Education. 26:31. 1939.


Hunter, R. S. A performance test involving accuracy, finish, and time. Industrial Arts and Vocational Education. 31:13-14. 1942.


McPhee, J. A. California conference notes on the point system of grading farm mechanics. Agricultural Education. 5:72. 1932.


Slanger, E. S. A plan for grading farm shop work. Agricultural Education. 8:106. 1936.


X. APPENDIX
Job No. 1 - Make framing square hanger

Material: 1 - 1" X 4' X 10" White Pine

Tools and Equipment: Crosscut saw, square

Procedure:
1. Select a working edge. Make measurements from this edge.
2. Square one end. Measure and cut to length.
3. Saw to proper width.
4. Mark angle and cut to size.

Plan:
Figure 1
Materials and job product for job 1, making
a framing square hanger
Job No. 2 - Lay out pattern for funnel

Material: 1 piece 5" X 6" paper or galvanized iron

Tools and Equipment: Compass or dividers, scissors or tin-snips, ruler or square

Procédure:
1. Find point three inches from three sides of material and draw arc.
2. Lay out pattern as shown in sketch.
3. Allow 1/4" for lock seam and 1/8" for lap seam.
4. Cut out carefully along the lines.

Plan:
Figure 2

Materials and job product for job 2, making

a funnel pattern
Job No. 3 - Make 1" eye from 3/8" round mild steel

Material: 1 piece 3/8" X 8" round mild steel

Tools and Equipment: Forge, anvil, tongs, center punch, ball pein hammer.

Procedure:
1. Determine amount of material to make eye.
   Length = (Inside diameter + stock diameter) X 3 1/7
2. Mark length with center punch.
3. Heat area to be bent.
4. Bend to 90° at mark.
5. Bend tip end around small part of the horn.
6. Close eye and center with rest of stock.

Plan:
Figure 3

Materials and job product for job 3,

turning an eye
Job No. 4 - Cut 2" NC threads on 3/8" stock

Material: 1 - 3/8" X 8" round mild steel

Tools and Equipment: Tap and die set, cutting oil

Procedure:
1. Make sure stock is straight and suitable for threading.
2. Square end.
3. Chamfer end slightly for better appearance and ease in starting threads.
4. Select proper die from set -- 3/8" NC.
5. See that die is properly adjusted and assembled.
6. Start with die in proper alignment.
7. Use thread cutting oil.
8. Back up die occasionally to break thread.
9. Cut to proper depth.
10. Check with nut. Nut should turn readily by hand but not be loose.
11. If nut is too tight, cut deeper thread.

Plan:
Figure 4

Materials and job product for job 4,
cutting threads
Job No. 5 - Weld 4" butt joint with arc welder

Material: 2 pieces 3/16" X 1" X 4" 
1/8" or 5/32" mild steel electrodes

Tools and Equipment: Arc welder and arc welding equipment

Procedure:
1. Tack metal to 1/16" --30° from vertical on each piece.
2. Place pieces so they are separated approximately 1/16".
3. Select proper electrode.
4. Set welder at proper heat.
5. Run practice bead on scrap piece and adjust heat as necessary.
6. Tack ends of weld.
7. With spread bead make single pass weld. Completed weld should be slightly higher than the level of the plates.
8. Allow the weld to cool slowly. Remove slag and inspect.

Plan:
Figure 5

Materials and job product for job 5,

making a butt weld
Job No. 6 - Remove and replace ledger plate

Material: Guard with old ledger plate
          New ledger plate
          Ledger plate rivet

Tools and Equipment: Mower guard repair block, drift punch,
                     3/16" pin punch, ball pein hammer, wire brush,
                     cold chisel.

Procedure:
1. Place guard in the repair block.
2. Drive rivet through the ledger plate using a drift punch.
3. Use pin punch to drive rivet through guard.
4. Clean out dirt from ledger plate recess.
5. Place new ledger plate in position.
6. Put in rivet from the top side.
7. Set rivet post under head of rivet and rivet firmly in place.
8. Chisel off end of rivet flush with ledger plate.
Figure 6

Materials and job product for job 6, removing and replacing ledger plate
EVALUATION

Job No. 1 - Make framing square hanger

Deviations from check points:

Place hanger so that the base corner and side are as indicated. Count the total number of deviations from the check points.

Angle of sawing:

With a protractor square measure the deviations in degrees from the 90° mark for each of the four saw cuts. The total number of these deviations is to be entered in the blank above.

Smoothness in sawing:
Check the appropriate number on the scale.

Give your estimate of the quality of the completed job. Check appropriate number on scale.

Time to complete job:

_______ minutes
Job No. 2 - Lay out pattern for funnel

Deviations from check points:

Place pattern on base corner and base side. Count the total number of deviations from the check points.

Give your estimate of the quality of the completed job. Check appropriate number on scale.

5 4 3 2 1
unsatisfactory excellent

Time to complete job: _________ minutes
Job No. 3 - Make 1" eye from 3/8" round mild steel

**Deviations from gauge:**
Place eye on gauge as shown in sketch. Be sure that the portion of the stock next to the eye falls between the guide lines and that the inside of the loop is placed at equal points on lines A and B. See sketch. Count the total number of deviations from the base lines.

![Sketch](image)

**Deviations from flat surface:** (in 16ths of an inch) Number
Place eye and stock on flat surface and measure in 16ths of an inch the largest gap from the surface. See sketch.

Are hammer marks observable? Check appropriate number on scale.

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Has metal been burnt?
Check appropriate number on scale.

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Give your estimate of the quality of the completed job. Check appropriate number on scale.

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Time to complete job: _______ minutes

**Sketch 1**
1 deviation
2 deviations
no deviations
5 total deviations from base lines

**Sketch 2**
2 deviations from flat surface
2/16" gap
Scale
Job No. 4 - Cut 2" NC threads on 3/8" stock

Deviations from length:
Place threads upon gauge. Count number of deviations if first complete thread lies outside limit marks.

Number_____

Number of chip marks:
Count all chip marks which are 1/16" or larger.

Number_____

Does nut run satisfactorily?
Check appropriate number on scale.

very tight
very loose
snug but
turns readily

Number_____

Give your estimate of the quality of the completed job. Check appropriate number on scale.

unsatisfactory
excelent

Number_____

Time to complete job: ________ minutes
Job No. 5 - Weld ½" butt joint with arc welder

What is the general appearance of the weld? Consider smoothness of surface weld, regularity of beads, and amount of spatter. Check appropriate number on scale.

Are slag inclusions present? Check appropriate number on scale.

Is undercutting present? Check appropriate number on scale.

How strong is weld? Place weld in heavy vise with weld seam slightly above jaws. With heavy hammer or sledge bend weld 90° toward bead surface. See sketch below. Check appropriate number on scale.

How deep is penetration? Check appropriate number on scale.

Give your estimate of the quality of the completed job. Check appropriate number on scale.

Time to complete job:

---

[Sketch of welded joint]
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Regression equations for job 1, making a framing square hanger:

**Within + Evaluator**
\[ y = 0.0574996288x_1 + 0.373526185x_2 + 0.42696087x_3 \]

**Within + Class**
\[ y = 0.0560608975x_1 + 0.253472x_2 + 0.60770361x_3 \]

**Within + Interaction**
\[ y = 0.056823913x_1 + 0.03980681x_2 + 0.60102777x_3 \]

**Within alone**
\[ y = 0.0569183511x_1 + 0.4055347x_2 + 0.59923552x_3 \]

where, in deviation form

- **y** = general estimate of quality in laying out and sawing framing square hanger
- **x_1** = number of deviations from check points
- **x_2** = number of deviations in angle of sawing
- **x_3** = value assigned for smoothness in sawing
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**Source**: Sum of squares and sums of crossproducts for Job 2, making a dummy pattern

*Table 13*
Regression equations for job 2, making a funnel pattern:

Within + Evaluator
\[ y = 0.11286437x \]

Within + Class
\[ y = 0.11607972x \]

Within + Interaction
\[ y = 0.11388449x \]

Within alone
\[ y = 0.11397484x \]

where, in deviation form

\[ y = \text{general estimate of quality in laying out a sheet metal pattern} \]

\[ x = \text{number of deviations from check points} \]
Table 14

Sums, sums of squares, and sums of crossproducts for job 3, turning an eye

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Regression equations for Job 3, turning an eye:

Within + Evaluator

\[ y = 0.1205952065x_1 + 0.2538754915x_2 + 0.2790107226x_3 \\
+ 0.2097865302x_4 \]

Within + Class

\[ y = 0.1312062591x_1 + 0.2081783440x_2 + 0.3120258495x_3 \\
+ 0.2133934552x_4 \]

Within + Interaction

\[ y = 0.1166695260x_1 + 0.2205515932x_2 + 0.3158408882x_3 \\
+ 0.2199195385x_4 \]

Within alone

\[ y = 0.1269090907x_1 + 0.2117870107x_2 + 0.303518747x_3 \\
+ 0.2509369180x_4 \]

where, in deviation form

\[ y = \text{general estimate of quality in turning eye for eyebolt} \]

\[ x_1 = \text{number of deviations from gauge} \]

\[ x_2 = \text{number of deviations from flat surface} \]

\[ x_3 = \text{score on presence of hammer marks} \]

\[ x_4 = \text{score from degree of burning of metal} \]
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**Notes:**
- **689** refers to the sum of squares, and sums of cross-products for job 1, cutting through these.

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Regression equations for job 1, cutting threads:

Within + Evaluator
\[ y = 0.054881996x_1 + 0.12782561x_2 + 0.58023407x_3 \]

Within + Class
\[ y = 0.052638286x_1 + 0.1269063x_2 + 0.58078038x_3 \]

Within + Interaction
\[ y = 0.058515765x_2 + 0.12557553x_2 + 0.57773788x_3 \]

Within alone
\[ y = 0.056366491x_1 + 0.12584933x_2 + 0.58082833x_3 \]

where, in deviation form

\[ y = \text{general estimate of quality of cutting threads on end of eyebolt} \]

\[ x_1 = \text{number of deviations in length} \]

\[ x_2 = \text{number of chip marks} \]

\[ x_3 = \text{score on fit of threads} \]
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Regression equations for job 5, making a butt weld:

Within + Evaluator

\[ y = 0.267890983x_1 - 0.051681106x_2 - 0.038107027x_3 \\
+ 0.10579571x_4 + 0.32661553x_5 \]

Within + Class

\[ y = 0.27298673x_1 - 0.023551175x_2 - 0.008253859x_3 \\
+ 0.35042211x_4 + 0.33739289x_5 \]

Within + Interaction

\[ y = 0.25563678x_1 - 0.01042605x_2 - 0.003422376x_3 \\
+ 0.36131093x_4 + 0.33778050x_5 \]

Within alone

\[ y = 0.270030995x_1 - 0.01369346x_2 - 0.013037296x_3 \\
+ 0.35066167x_4 + 0.33949437x_5 \]

where, in deviation form

\[ y = \text{general estimate of quality of butt weld} \]

\[ x_1 = \text{score on general appearance of the weld} \]

\[ x_2 = \text{score on amount of slag inclusions} \]

\[ x_3 = \text{score on degree of undercutting} \]

\[ x_4 = \text{score on strength of weld} \]

\[ x_5 = \text{score on depth of penetration} \]