THE RETENTION OF SECONDARY SCHOOL METALWORKING KNOWLEDGE AND SKILLS FOLLOWING THREE MONTHS OF NO TRAINING

By

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Abstract

An underlying assumption of an educational system is that the learning which takes place will be of present and future use to the learner. When this learning is not retained well, this underlying assumption is called into question. In no subject area is the use of learning a greater priority than in Industrial Education. Here the value of knowledge and skills is largely dependent on usefulness to the learner.

For the present study the researcher developed two measuring instruments. One was a multiple choice instrument that measured knowledge that was needed in the development of psycho-motor skills, and knowledge that was not so needed. Both of these types of learning were separated into mastery level learning and non-mastery level learning. The other instrument measured level of achievement of a continuous psycho-motor skill, namely arc welding.

Tests were administered in June to a class of Metalwork 11 students, then administered again in September to the same students as they entered Metalwork 12. Multivariate analysis of variance tests were conducted to determine any differences in retention rates.

The results indicated that knowledge used in the development of psycho-motor skills was retained well, as was the psycho-motor skill itself. Mastery level learning suffered significant losses unless it was used in the development of skills. Knowledge not used in the development of skills suffered significant losses. Several variables were investigated to determine their effects on retention of these types of knowledge.

This study is of use to administrators and Industrial Education teachers as they decide on appropriate methods of implementing Industrial Education curricula.

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An education, it appears, is not a solo effort. One person's decision to spend two years of study affects many others. Several very significant "others" in my life have shared in the labour, although it is primarily I that receive the benefit. I would like to express deep appreciation to these people:

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Chapter 1

The Problem in its Setting

1.1 Outline of the problem

Industrial Education aims to teach skills, concepts and knowledge that are of immediate use as well as useful in the future for the student. It is this emphasis on practical use of the content of the courses, as well as the thinking and problem solving skills, that demands studies of curriculum retention.

It appears that it is the immediate need of the armed forces to have the learning and the skills retained and available that prompts the studies of retention that have been done for the Forces [34,42,72,77,81]. Similarly, it is the recognition of the importance of retention that motivates the readily available studies of retention of first-aid training [60,87,104]. While public schooling does not generally involve life or death crises, as in the armed forces and in first aid, it does hopefully involve a significant amount of valuable training which should also be retained to be of use.

Industrial Education knowledge and skills are taught not only to develop thinking skills and problem solving, but also to be useful in and of themselves. Obviously when benefits of education are lost due to lack of retention, the knowledge and skills are no longer useful. Despite this rather self-evident fact, studies investigating the retention of Industrial Education curricula are virtually non-existent. Retention studies in general are often not generalizable to practical "real life" situations, having been conducted in clinical situations. Arzi, Ben-Zvi, and Ganiel [7] criticized retention studies:

> A major problem with retention studies concerns their ecological validity, since many of them were conducted within the framework of psychological laboratory experiments on immediate recall of fragmentary information. (p.171)

Our limited understanding regarding retention of technical knowledge and its related psycho-motor skills is gained primarily from studies of technical skill retention done for the United States Armed Forces [2,76,78]. However, many problems remain unsolved: whether or not the retention of secondary school students differs in this area from that of soldiers, whether or not our system of training in secondary school produces a pattern of retention different from that produced in the armed forces, and identification of the types of learning that students find difficult to retain.

Other studies have brought about increases in understanding of retention of cognitive skills such as map reading [21], mathematics concepts [93], narrative material [97], teaching skills [48], and second languages [10]. Here the same problem remains; to what extent does information about retention in these areas generalize to the curriculum area of Industrial Education, specifically Metalwork?

In secondary school Metalwork courses, which are becoming known as Metal Technology as the evolution of Industrial Education follows our increasingly technological society, the curriculum promotes learning in the cognitive domain through self study, lecture, and exploration of historical and modern methods of working with a variety of metals. Psycho-motor skills are developed through opportunities for students to practice and improve these skills as they work through processes used in related businesses and industries. Thus students are expected to know and understand a body of factual knowledge, as well as to have acquired skills typical of the current practice of metalworking technology. In both of these areas the needs of the student specific to the local communities are an important consideration in implementing the curriculum.

Industrial Education teachers must find a balance in emphasis between the teaching of factual knowledge and the development psycho-motor skills. Different Industrial Education teachers find greatly varying balances, from the teaching of only factual knowledge to the teaching of only psycho-motor skills.

This study grew out of a desire on the part of the researcher to determine the relative retention rates of the factual knowledge and psycho-motor skill areas of the Metalwork 9/10, 11, and 12 curricula. Specifically, this study intended to ascertain how much of the original learning in these domains is available for use by the student several months after secondary school study ceases.

The first, and most obvious, area of research involved exploring the possibility that psycho-motor skills are retained to a different extent than is factual knowledge. These are the two main types of learning pursued in Metalwork and in Industrial Education as a whole. Further, these two areas of learning represent quite different methods of learning (activity based versus verbal based). This distinction may well also affect rates of retention.

It is expected that there will be overlap between 'knowledge' and 'skills', both in the learning process and in the resulting learned material, principles, and concepts. A substantial portion of the knowledge gained will be needed in the development of the psycho-motor skills, with one reinforcing the other.

Factual knowledge includes content that does not directly relate to the learning of psycho-motor skills. Content such as the history of machining or the manufacture of steel fits into this category. Other factual knowledge content forms a necessary part of the development of psycho-motor skills. The considerations applied, and the mathematics used in determining the speed settings of a lathe are examples of factual knowledge content that is used in developing psycho-motor skills.

If skills are retained at a different rate than factual learning, a possible factor in the rate of retention of factual learning may be the use, or lack of use, of this factual knowledge in the development of psycho-motor skills.

This consideration must be differentiated from the level of initial learning, because a topic that is learned very well may be retained at a rate different from the rate of retention of topics that are not learned well initially. This may confound results that should be attributed to other variables. This study will investigate this possibility.

Achievement levels vary in any group of students. It is possible that this variation may help to explain differences in rates of retention. Three independent variables, that relate to achievement levels, merited exploration. Academic or non-academic major, overall achievement in school courses, and achievement in the subject area were each used as achievement measures, and were each explored for possible retention variations.

In order to measure rates of retention, a time period of no instruction was used as the "treatment". This retention interval was the summer vacation of 1988, and amounted to twelve weeks. Generally no study was undertaken by students during this interval, but a questionnaire revealed that several students had practiced the sample psycho-motor skill. This was then incorporated into the study as a variable that may affect retention level.

The present study is an exploratory study in the area of retention of Industrial Education curricula. Because this topic has not previously been researched, the choice of variables was based on logic and experience in the Industrial Education field. However, the effect of these variables on retention of psycho-motor skills and factual knowledge, as measured in other areas of learning, is discussed in detail in Chapter 2.

1.2 Statement of the Problem

The specific problem that this study will explore is:

How well are the knowledge and skill areas of the Metalwork 11 curriculum retained by students entering Metalwork 12 after a three month period of no practice, and what other factors might influence the rate of retention?

1.2.1 Research Questions

In gathering information regarding this problem, several possibly related factors will be studied:

1. Are continuous psycho-motor skills retained at a higher level than is the knowledge used in developing the skills?

2. Is the knowledge that is used in skill acquisition retained at a higher level than is knowledge not used in skill acquisition?

3. How much of this difference can be related to high levels of learning?

4. Does a predominantly academic background produce different retention patterns than does a predominantly non-academic background?

5. Do students with overall higher marks in core courses have a different rate of retention than do those with lower levels of achievement?

6. Do students with overall higher marks in Metalwork 11 have a different rate of retention than do those with lower marks?

7. Does skill practice during the retention interval affect retention levels?

1.3 Hypotheses

The following hypotheses will be stated as a sentence in their null form, then symbolically in null (H_O) and alternate (H_A) forms. Difference (Diff) refers to the difference in scores between the June and September administration of the measuring instruments, and is therefore a measurement of the forgetting that took place.

To address the research problem and its possible contributing factors, these null and alternative hypotheses will be tested:

1. Continuous psycho-motor skills (PM) will not be retained at a significantly higher percentage than the knowledge used (UK) in acquiring skills.

   - H_O: $X_{diff_{PM}} = X_{diff_{UK}}$
   - H_A: $X_{diff_{PM}} < X_{diff_{UK}}$

2. Knowledge used (UK) in acquiring skills will not be retained at a significantly higher percentage than knowledge not used (NUK) in skill acquisition.

   - H_O: $X_{diff_{UK}} = X_{diff_{NUK}}$
   - H_A: $X_{diff_{UK}} < X_{diff_{NUK}}$

3. Group mastery learning (M) will not produce a significantly lower retention level than is found in the group non-mastery (NM) knowledge areas.

   - H_O: $X_{diff_M} = X_{diff_{NM}}$
   - H_A: $X_{diff_M} > X_{diff_{NM}}$

4. Students enrolled in two or more Industrial Education electives (IE) will not retain a significantly different amount of knowledge not used in psycho-motor

skill development (NUK) than will students enrolled in two or more academic electives (AE).

- H_O: $X_{diff_{IE_{NUK}}} = X_{diff_{AE_{NUK}}}$
- H_A: $X_{diff_{IE_{NUK}}} \neq X_{diff_{AE_{NUK}}}$

5. Students enrolled in two or more Industrial Education electives (IE) will not retain a significantly different amount of psycho-motor skills (PM) than will students enrolled in two or more academic electives (AE).

- H_O: $X_{diff_{IE_{PM}}} = X_{diff_{AE_{PM}}}$
- H_A: $X_{diff_{IE_{PM}}} \neq X_{diff_{AE_{PM}}}$

6. Students with a grade point average which falls in the top one third of the class (HGPA) in the core areas will not have a significantly different rate of retention in all measured areas of Metalwork 11 curriculum than do students with a GPA in the core subjects which falls in the bottom one third of the class (LGPA). See definitions on page 8 for an explanation of the GPA system.

- H_O: $X_{diff_{HGPA}} = X_{diff_{LGPA}}$
- H_A: $X_{diff_{HGPA}} \neq X_{diff_{LGPA}}$

7. Students with high metalwork marks (HMM) in the Metalwork 11 course (top 25% of year average marks) will not retain a significantly different amount of all measured Metalwork 11 curriculum areas than students with low marks (LMM) in Metalwork 11 (bottom 25% of students).

- H_O: $X_{diff_{HMM}} = X_{diff_{LMM}}$

- H_A: $X_{diff_{HMM}} \neq X_{diff_{LMM}}$

8. Students who practice a psycho-motor skill (PR) during the retention interval will not retain that skill at a higher level than students who do not practice that skill (NPR) during the retention interval.

   - H_O: $X_{diff_{PR}} = X_{diff_{NPR}}$
   - H_A: $X_{diff_{PR}} < X_{diff_{NPR}}$

Significance in these hypotheses refers to statistical significance at a level of confidence of .05. A level of .05 rather than .01 was chosen because of the exploratory nature of the research. With no available research in the area of retention of Industrial Education course content, a .05 possibility of a Type 1 error was accepted in order to reduce the possibility of overlooking true differences in retention levels (a Type 2 error).

On the other hand, a .10 level of confidence was rejected because it raised the possibility of a Type 1 error to an unacceptable level, especially in view of the fact that a reasonably large number of variables were being investigated.

1.4 Definition of Terms

Arc welding: Fusing together of two similar metals by heating, melting and adding more metal, all by means of a controlled electric arc, is referred to as arc welding. In this study arc welding can by defined as a psycho-motor skill involving setting a welding machine to correct current type and amperage, and manipulation of a welding rod so as to control welding bead width, evenness, spatter, and placing.

Continuous psycho-motor skills: These are skills that require constant movement control, such as tracking a moving point on a screen, with a stylus. These skills require cognitive skills such as decision making, as well as constant manual adjustment of some object.

Core courses: Core courses are school courses that all students must successfully complete in order to be eligible for graduation. For grades 10, 11 and 12 these are:

- Grade 10
  - Social Studies 10
  - English 10
  - Physical Education 10
  - Science 10
  - Mathematics 10
- Grade 11
  - Social Studies 11
  - English 11
  - A grade 11 science
- Grade 12
  - Social Studies 12
  - English 12
- Consumer education must be taken in Grade 9, 10, 11 or 12.

Grade Point Average: Grade Point Average (GPA) refers to a system of assigning numerical values to course grades for the purpose of facilitating averaging of marks. For the purposes of this study, these numerical values, in use at the schools attended by the research subjects, were used:

- A = 6
- B = 5
- C+ = 4
- C = 3
- P = 2
- F = 1

Group mastery Learning: For the purposes of this study, group mastery learning is defined as learning that produced a correct response rate of 70% to 100% when measured by the knowledge instrument.

Group non-mastery Learning: For the purposes of this study, group non-mastery learning is defined as learning that produced a correct response rate of 30% to 70% when measured by the knowledge instrument.

Metalwork curriculum areas: For the purposes of this study, the Metalwork 11 curriculum is divided into three areas:

1. Psycho-motor skills.
2. Knowledge used in the development of psycho-motor skills (termed *used knowledge* for the purposes of this study).
3. Knowledge not used in the development of these skills (termed *unused knowledge*).

Procedural skills: Skills of a technical nature that involve multiple discrete steps in the completion of a task are referred to as procedural skills. Here the order of steps is of concern, as well as the correct execution of the step. An example to a procedural skill is the safe setup of an oxy-acetylene torch. This involves several steps:

1. Check that regulator knobs are loose
2. Slowly open acetylene tank 1/2 turn
3. Slowly open oxygen tank, then open valve fully
4. Set line pressures
5. Bleed lines
6. Ignite acetylene
7. Slowly introduce oxygen to attain correct flame

Psycho-motor skills: These are motor skills that involve hand-eye co-ordination and physical manipulation of equipment, but also involve some cognitive skills (problem solving, critical thinking) as well as technical knowledge needed to set up and use the equipment. The successful operation of most metalworking machinery involves largely psycho-motor skills.

Welding Bead: The deposit of weld metal as a product of the arc welding process is the welding bead. Much can be determined about the skill of the person doing the welding by a close inspection of the weld bead.

1.5 Significance of the Problem

Through much of the United States and Canada increasing financial pressure has been placed on the Educational system, partially due to a continual desire for lower taxes, but recently primarily due to the recession of the late 1970's and 1980's. The British Columbia public educational system has not been immune to this trend.

The desire for educational cost effectiveness increasingly determines the conduct of education. In 1987 the Curriculum Development Branch of the British Columbia Ministry of Education continued to see the role of the Ministry as ensuring that:

> ...the Province's education system gives students an opportunity to receive a quality education in a cost-effective manner. [16, p.1]

This statement reflects two current and recurring trends in education: accountability and budget restraint. Programs and courses are being closely scrutinized to ascertain their quality. This is reflected in the reinstatement of governmental exams, and the increased graduation requirements, as well as the implementation of added 'core' courses in the British Columbia public school system. While this accountability move has been prevalent in recent years, the decreased monies available and increasing control over its expenditure has also resulted in increased pressure on educators to critically examine programs that tend to be expensive.

Although the negative results of accountability and financial restraint are identifiable, some of the educational introspection is doubtlessly valuable. Educators need to determine which parts of the curricula are worth retaining, which need improvement, and which are not worth continuing. Careful evaluation must surely be seen as a positive and a necessary component of sound educational decisions. Although current pressures have provided added impetus, the educational system must continually evaluate itself with the intent to improve.

Industrial Education is an area with a unique position in the accountability and restraint movements. Training for technological and industrial skills involves the use of expensive equipment and facilities. Where corporations justify large expenditures on capital equipment on the basis of potential profit, this justification is less obvious in educational spending. The expenditure of money to teach life-skill oriented technology courses similarly has little immediate financial return. Thus educators involved in a higher cost program of studies must take greater pains to evaluate and weigh the benefits of the program.

Similarly, the trend to increasing the number of required courses has left the student with fewer choices, and less ability to pursue his/her own interests. This means that fewer elective courses are needed, and, in order to survive, the available electives must ensure that they meet the needs of the student.

It is not only the imposition of the financial constraints and the pressure of the 'back to basics' movement that prompts study of Industrial Education curricula. Study into the retention of Industrial Education curricula is important for the same reasons that it is important in any field of education. If, for example, a curriculum is designed to teach an understanding of the production of iron and steel, and the student does not remember the process a few months later, the curriculum has not been successful. The same thing holds true for other topics, skills, and disciplines. A high level of retention does not necessarily indicate a high quality program, but low retention renders a program almost valueless, regardless of its potential.

On the other hand, if the areas of high and low retention can be identified, the implementation of the curriculum might be modified to facilitate an increased retention of weak areas, and possibly a decreased expenditure of valuable time on areas that are retained well. For example, studies have shown that safety steps are among the most poorly retained steps in technical procedural skills [50,81]. Considering the importance of such steps, surely it is vital that such steps be given special consideration. It is the study of retention that may lead to methods of improving retention where needed.

In the studies mentioned above, overlearning was identified as a contributor to retention. If this technique was applied to the safety considerations, retention would likely improve. What is needed are similar studies on the retention patterns of high school Industrial Education students. This study cannot attempt to investigate even a fraction of the great many variables that combine to produce a successful Industrial or Technical Education program. However, it is expected that some practical benefits and course improvements may result from gaining information regarding retention of three broad areas of the Metalwork 11 curriculum as implemented in a 'real life' situation.

Chapter 2

Review of the Literature

2.1 Introduction

This chapter will summarize the literature related to the problem as described in Chapter 1. The chapter will be divided into two sections. In the first section, literature dealing with psycho-motor skills will be reviewed, and the second section will review literature relating to retention of cognitive knowledge and skills. The literature in each of these sections will be organized according to the variables that the studies explored.

There is no available research that directly concerns the retention of knowledge and skills in the Industrial Education curriculum. There are, however, two sources of information that serve as a foundation for the present study. Research exists that delves into the retention of a variety of psycho-motor skills. Much of this retention research has been carried out by the United States Armed Forces in an attempt to assess the levels of competence of armed forces personnel. Military skills are similar to the skills that are part of the Metalwork curriculum, and relate to the welding skill that is examined in the present study. Included in this body of retention research are skills such as the operation of a great variety of machinery, tools, and equipment.

There is also an available body of research concerning the retention of various cognitive knowledge and skills. These studies encompass elementary school subjects, secondary school subjects, and post-secondary school subjects. From this literature base, this study will concentrate on subject areas with the greatest similarity to the

Metalwork curriculum; laboratory sciences and mathematics. Other less closely related curriculum areas will be briefly reviewed. Commonalities from this research on retention of knowledge can be used to infer hypotheses regarding the retention of the knowledge area of the Metalwork 11 curriculum.

It is the intention of this study to put these current findings on retention in a new light, by exploring how knowledge and skill areas of the Metalwork 11 curriculum work together and separately to affect retention of the curriculum.

2.2 Psycho-motor Skills

In this section attention will be focused on the factors that affect the retention of psycho-motor skills. Research exploring the effects of relevant variables will be reviewed to provide a foundation for this study.

2.2.1 Amount of Training

In the present study of the Metalwork 11 curriculum, it was expected that those areas of the curriculum that were learned to a high level, or possibly even overlearned, would be retained significantly better than curriculum areas that were not learned as well. These curricular areas included both skills and knowledge areas. The evidence from the following literature strongly suggests that higher levels of initial achievement result in higher levels of retention. This section will review important research regarding the effect of the amount of training on the retention of skills. Section 2.3.3.1 will deal with the effect of the level of achievement on knowledge areas.

Many researchers [5,22,28,38,41,62,66,73,77,78,107,110] have studied the effect on retention of mastery learning or overlearning of a variety of skills. With one exception, a study by Mengelkock, Adams, & Gainer [62], these studies found mastery learning to provide significantly improved retention. Although studies reported in Section 2.2.2 show that continuous skills are retained to a greater degree than procedural skills, both continuous and procedural skills show greater retention when overlearned.

Schendel and Hagman [77] studied the retention of the procedural skill of disassembly/assembly of an M60 machine gun, using 38 reserve soldiers as subjects. The control group was trained to the criterion of one errorless performance. A second group (group OT) was trained to the preceding criterion and then received 100% overtraining, repeating the number of trials that it took to gain one errorless performance. A third group (group RT) received this overtraining as refresher training, delaying it to halfway through the eight week retention period. After eight weeks group OT showed a 65% advantage over the control group in terms of errors made in retraining. Group RT showed a 57% advantage over the control group. These advantages were significant in both a statistical and practical sense, in spite of the small number of subjects in each group. The difference between groups OT and RT was not significant.

Goldberg, Drillings, and Dressel [34] found similar results but with qualifications. They overtrained their subjects on two military procedural tasks, one more difficult than the other. In this study, overtraining was defined as three correct performances as opposed to only one. While mastery produced better retention, this superiority was limited to the more difficult task, and disappeared after the first retraining trial. They appear to have overlooked the possibility that an easy task may be mastered well without the overtraining required to master a more difficult one. This study does not provide solid evidence that would contradict the conclusions of Schendel and Hagman [77] above.

In another study of the retention of a skill that appears to be largely procedural, Hagman [38] trained military personnel to test the charging system of a vehicle. The subjects were given zero to four overtraining repetitions during training, then retested after 14 days. He found that retention improved with the first three repetitions but leveled off after this. Apparently there may be a time in the extreme when the extent of overlearning becomes a non-significant factor. It is doubtful that this finding will affect the present study, since the subjects are learning welding for the first time in Metalwork 11. As a result, the highest level of achievement for this study is not likely to be classified as overlearning carried to extremes.

Several studies used both procedural skills and continuous skills to determine if higher levels of achievement produced greater retention. It appears that regardless of the type of psycho-motor skill studied, higher achievement is positively related to higher retention.

Ammons, Farr, Bloch, Neumann, Dey, Marion, & Ammons [5] studied procedural and continuous skills in a clinical setting. They trained college males in groups of 40 to 47, with some groups receiving 5 trials and some groups 30 trials, on a procedural task. Retention was tested at 1, 6, 12, and 24 months. To test the retention of the continuous skill, similar groups were given 1 or 8 hours of training. The results for both types of skills showed that although absolute loss was greater for the highly trained groups, relative loss was less. In the present study relative loss will be the important issue. Ammons, *et al.* indicate that lower achievers lose a greater percentage of their skill than do higher achievers.

Using smaller groups of sixteen subjects, Naylor, Briggs, & Reed [66] also studied the retention of both procedural and continuous skills in a clinical setting. Their conclusion supported Ammons, *et al.* [5] when they found that the amount of training was the most important variable in the retention of these two types of skills.

Two studies [28,41] in the early sixties concentrated on the retention of difficult continuous skills. Hammerton [41] found that loss was greater than expected, likely because the difficulty of the task reduced the likelihood of mastery in the training period. However, there was a significant difference in the relative loss of skill between higher and lower trained groups.

Fleishman & Parker [28] found that retention patterns were a "function of *level of proficiency* at the end of initial training rather than the *type* of initial training used in this study" [28, p.223]. They too had used a "highly complex continuous control task" [28, p.215], and found that the relationship between level of original learning and retention remained quite constant and high during retention periods of up to two years. Others [34,73,110] have found similar results.

In disagreement with these findings, Mengelkoch, Adams, & Gainer [62] found that a difference in training of 5 versus 10 trials in an instrument flying skill did not make a significant difference in the degree of retention after four months. However, while the 10 trial group did not retain a significantly higher *proportion* of original learning they did retain a higher *absolute* amount of learning, but this still leaves the primary findings in contradiction to the findings of the majority of other studies. While the authors offer no explanation for this inconsistency, one possible explanation is the small sample used (only 13 subjects in each of two groups). Another explanation might relate to the possibility that the task was so simple that overlearning had already taken place after five trials. As previously noted, Hagman [38] found that after three trials there was little further improvement in retention provided by a fourth trial.

Some generalizations are provided by others who have reviewed this type of research. Gardlin & Sitterly [30], Hagman & Rose [40], Naylor & Briggs [66], Rose, McLaughlin, Felker, & Hagman [76], Schendel, Shields, & Katz [78], Stammers [90], and Wright [109] all reviewed retention of psycho-motor skill research. Each concluded that the level of initial learning is an important determinant of retention of psycho-motor skills. While none of these studies were set in secondary schools, they do provide some guidelines for research regarding retention of skills by secondary school students. Level of original learning in the arc welding skill will be one variable that must be considered as a possible explanation of retention patterns in this study.

As mentioned in Section 2.2.1, the results found by several researchers [28,34,73,110] indicate that the effect of level of initial learning produced consistent results within a broad range of retention intervals, with level of original learning being the most important variable studied. One study compared the effects of amount of training or experience to the length of retention interval. Using aviators with varying experience and varying lengths of time since their last flight, Wilson [107] found that amount of experience had a significant effect on retention, but retention interval did not. Although Wilson's sample was very small, his conclusions are in agreement with other research.

The present study used the summer months, a period of approximately 12 weeks, as the retention period. The implication of the previous research for the present study is that consistent results, in terms of the effects of amount of original learning on skill retention, would likely be found with retention intervals that are somewhat shorter or longer, at least up to two years.

2.2.2 Procedural versus Continuous Skills

In this study, arc welding is the skill that is used as an example of a psycho-motor skill. While there are some slight procedural aspects to this skill, arc welding was chosen because it is primarily a continuous skill. Continuous skills are least similar to verbal learning, while procedural skills can, to some extent, be learned in a verbal manner [68], and evaluated in a verbal or written manner. It may be argued that a truly procedural skill need not have a motor component to it at all, and therefore may not be a psycho-motor skill at all. In attempting to determine any differences in retention between psycho-motor skills and cognitive learning, or to see how the two different types of learning work together, it is useful to choose a skill that is quite dissimilar to academic learning.

Several studies [1,5,62,78,84,85,86] have documented differences between procedural and continuous skills in terms of retention patterns. Although level of original learning has similar effects on the retention of procedural and continuous skills, there appear to be some other noteworthy retention differences that in part led to the choice of a continuous rather than a procedural skill for the present research.

In their study of the learning and relearning of a flight maneuver, Adams & Hufford [1] found that the procedural aspects of the maneuver showed large losses over a 10 month period, with scores deteriorating from 95% correct to 5% correct. Procedures were scored by crediting a zero for an omitted step, 1 point for a step in the right sequential place but executed too slowly or too quickly, and 2 points for correct sequence and timing. Continuous skills, such as the control of the amount of banking in a turn, showed a deviation of less than 2% of the banking angle. This was statistically but not practically significant. Minimal forgetting was also found by Mengelkoch, Adams, & Gainer [61] in a very similar task.

Using a different system of measurement, Ammons, *et al.* [5] also found much higher percentages of forgetting for procedural tasks than for continuous tasks. They measured time taken to complete a procedural task, and found that the time required increased by a factor of 2.68 after one month, and by a factor of 4.28 after two years. A continuous control task was scored by measuring the amount of time per minute that a simulated airplane could be kept straight and level. Time on target remained almost unchanged from 83.4% at 24 hours to 83.5% at one month and then decreased to 76.9% at two years. Error here increased by a factor of 1.39 over two years, compared to 4.28 for the procedural tasks. (see page 18 for more information regarding this study)

Mengelkoch, *et al.* [62] also used an aircraft flight simulator, in this case measuring the forgetting of instrument flying skills. They concluded that:

> ...procedural responses show retention losses that are not only statistically but practically (operationally) significant whereas measures of proficiency for flight parameters are operationally insignificant throughout, even in the instances when they are statistically significant [62, p.405].

Schendel, *et al.* [78], in their review of psycho-motor skill retention, found that in general procedural skills are forgotten in days, weeks, or months, while continuous skills are remembered for months or years. Sitterly [84], Sitterly & Berge [85], and Sitterly, Zaitzelf, & Berge [86] found that the degradation of a continuous control skill was moderate for the first 3 months, then error increased more rapidly to two to three times at 6 months. Procedural skills, measured in terms of time taken, were degraded by a factor of 5 after 1 month and a factor of 17 after 4 months (see page 26 for further information regarding these studies).

Four possible reasons are suggested for the difference in retention of procedural and continuous skills:

- the verbal cognitive nature of procedural tasks reduces retention;
- continuous tasks may generally be overlearned in relation to procedural tasks;
- continuous tasks may be better retained because they are more coherent and integrated, with each action naturally leading to the next; and
- it may be easier to score slight decrement in a procedural task than it is in a continuous task [78].

The last suggested reason seems to be questionable, since the results of retention studies indicate that there is often large decrement in procedural tasks. The sizes of the decrements, combined with the consistency of the findings, would indicate that the results are not an artifact of the measuring instruments.

One major problem in accounting for the observed differences between retention of procedural and continuous tasks is the problem of equating the learning and scoring of two different classes of responses. However, the scope of the present study requires only the awareness that continuous motor skills are generally found to be more resistant to forgetting than procedural skills. While it appears possible that equating these skills on the basis of task organization and level of training may result in similar retention decrement effects [66], in a classroom situation these controls are not possible. It is more accurate in this case to rely on the less strictly controlled research findings, which have attempted to reflect actual, rather than contrived, learning situations.

It appears that continuous skills are less closely related to academic learning than are procedural skills. This is not only because continuous skills are less likely to be verbally learned than procedural steps may be, but also because the retention of continuous skills is generally much higher than that of both procedural skills and academic knowledge (see Section 2.3, page 32).

Psycho-motor skills often have both procedural and continuous components to them. It is difficult to conceive of a skill that is entirely procedural or entirely continuous. Arc welding is procedural in that there are certain steps required to set the machine to correct amperage setting and current type, and to prepare the work for the actual arc welding. The welding operation itself is primarily a continuous control skill, constantly adjusting the welding rod for angle, arc length, rate of travel and consistency of motion. Arc welding can be expected to be retained very well because of this large continuous skill component, if existing findings generalize to the secondary school setting.

2.2.3 Distributed versus Massed Practice

There is evidence in the literature that the way skills are learned also has an effect on the retention of these skills. In Metalwork 11 most skills are gradually learned throughout the school year. Skills are introduced early in the year, then students are given the opportunity to use these skills during the year as they create the project or projects of their choice. The learning experience continues throughout the year. Several studies have compared this method of learning with a training experience that is massed into a short period of time.

Training soldiers to perform a maintenance check on vehicle battery charging systems, Hagman [39] repeated his earlier study [38], but compared training by condensing three sessions in 1 day as opposed to spreading them out over 6 days. He found that while there was no difference in the level of initial learning, after 14 days the spaced training groups retained significantly more than the massed training group.

In a study that is more clinical in its setting, Reynolds and Bilodeau [74] conducted three related experiments to determine the effects of spacing of practice sessions. Three continuous skills were used. In a rudder control experiment, a massed group was given twelve 30 second trials, while a distributed group was given a 30 second rest between each of the trials. The second experiment used a complex coordination test, with subjects receiving eight repetitions of a sequence of 40 steps. Distributed groups received rests of 12, 60, or 120 seconds between sequences. A rotary pursuit task was used in the third experiment, with six seconds on target being one trial. Groups were given 20 trials. Rest lengths were 0, 12, 60, and 120 seconds.

Several results were apparent. Learning was significantly greater with the spaced practice groups as compared to the massed practice groups, and this difference was apparent fairly early in the training. At the end of the ten week retention period this difference still existed but decreased upon further training after the retention interval.

Confirming these results, Jahnke & Duncan[44] researched retention of a continuous pursuit motor skill. Spaced training groups received very short periods of training (10 seconds) separated by 20 second rest periods, for a total of six minutes of training.

Massed groups received the six minutes of training continuously. Retention was significantly higher for the spaced practice groups over retention periods of one day, one, two, three, or four weeks.

Since the subjects in the present study tend to have their practice sessions spaced over a period of many days (approximately 200) their retention of skills should not be negatively affected. Practice sessions are not spaced by the relatively short intervals often researched [44,74], but do resemble the longer periods used by Hagman [39], so the conclusions likely generalize to the present study.

2.2.4 Practice During Retention Interval

Educators hope that the material being studied by the student is relevant to that student. Relevance, in the area of Industrial Education, includes the expectation that students will make use of the variety of skills learned. Intuitively, it seems that use of a skill should enhance its retention. In the present study one group of students used the arc welding skill, or related skills, over the retention interval, while a second group did not. This section will review research that has presented certain conclusions that tend to confirm intuitive judgement regarding the possible effects of skill use in the area of retention.

Concentrating on procedural skills, Naylor, Briggs, & Reid [66] wished to determine the effects of rehearsal during the retention period. They used four groups of subjects. Two groups rehearsed only parts of the task, one rehearsed the complete task, and the fourth group did not rehearse at all. Initial training was accomplished in 5 days, then there were 9 days of no practice, 5 days of rehearsal, 10 more days of no practice, and finally a retention test. In this procedural task, no overall significant difference was found in retention among the four groups, indicating that rehearsal has little or no overall significant effect. Only when various parts of the procedure were analyzed separately was some significance found. However, because no overall significant differences were found, the individual differences found later should not be considered significant. It is highly probable that they occurred only because some significant differences will be found if enough tests are done, purely on the basis of chance. When the omnibus test did not find significant differences further individual tests should not have been conducted.

However, a similar study conducted by Shields, Goldberg, & Dressel [81] showed that six military skills were not retained significantly better with refresher training than they were without this training. This result however is weakened somewhat by some of the characteristics of the task. Job aid manuals were used during the testing, and the no-refresher retention period was prior to the refresher training period, using the same group. This tends to confound the effect of length of retention interval and the effect of refresher training.

Three related studies were carried out by Sitterly [84], Sitterly & Berge [85], and Sitterly, *et al.*, [86]. These studies investigated retention of flying skills, both continuous and procedural, over a period of six months. Their results differed quite dramatically from those of Naylor, Briggs, & Reid [66]. Rehearsal was carried out in several ways including dynamic (hands on), and static (hands off), and was either distributed over the retention period or non-distributed.

In this study, rehearsal was significantly effective in maintaining both the procedural and the continuous control skills, but more effective for the procedural skills. Simple static rehearsal techniques were sufficient to maintain both types of skill at a high level for the six month retention interval.

Hagman [37] found some positive effects of practice on retention using typewriting over a period of about a month. He found that without practice there was substantial decrement in skills, while practice improved the speed of typewriting but did not significantly reduce errors.

In a study that used the procedural skill of assembly and disassembly of an M60 machine gun, Schendel and Hagman [77] investigated the effects of refresher training on three groups. One group had no refresher training, one had refresher training midway through the eight week retention interval, and the third group had the equivalent amount of training placed immediately following the initial training.

Both of the groups receiving extra training retained greater than 50% more than the non-refresher group. Placing of the extra training did not have a substantial effect on retention. In this study it would have been useful to have had another group that received additional training initially and also received refresher training, to examine the interaction effects. Perhaps refresher training has a significant effect if the material is learned to a mastery level. Apparently the question has yet to be answered.

The present study will measure level of skill learning prior to the retention period, then compare the effects on retention of level of arc welding achievement and practice during the retention interval. Research does not yet give clear direction in this area, but it is an important consideration. Many students use parts of their acquired skills over the summer months, and this may well have an effect upon their skill levels at the end of summer.

2.2.5 Difficulty of the Task

In the research on retention of tasks that are primarily procedural, consistent results have shown that a longer procedure, or one with difficult steps, is more susceptible to forgetting [40,70,81]. The continuous skills that apply more directly to the Metalwork 11 curriculum have seen little research that employed difficulty as a variable. The research which is available is inconclusive.

Hammerton [41] investigated the question of whether a very difficult continuous control skill is retained as well as existing research showed average continuous skills were. Bilodeau & Bilodeau [13] had previously shown that continuous skills were retained almost perfectly over extended time periods. Eighteen of Hammerton's colleagues volunteered to learn a very difficult tracking task. One group learned to a preset criteria, and another overlearned by approximately doubling the practice time. After 26 weeks of no practice the subjects relearned to original level. Hammerton's results differed from Bilodeau & Bilodeau in that he found significant but not substantial loss of skill for both groups, though less for the mastery group. However, relearning was rapid for both groups. There is room for doubt as to the generalizability of this study to secondary school groups, since Hammerton's sample used highly educated individuals involved in research.

In a very similar study, Battig, Nagel, Voss, & Brogden [12] served as their own subjects in learning a very difficult tracking task. They practiced for 100 days, with their skills improving very slowly due to the difficulty of the task. After about eight months, three of them were retested (one member was unable to complete the study). Retention was found to be very high, but again questions regarding generalizability must be asked when only three subjects completed the study, and each was a researcher. Application to the present study is possible, but far from certain.

Youngling, Sharpe, Ricketson, & McGee [110], on the other hand, found that performance showed *smaller* decrements for more difficult tasks. They also used an image motion compensation (tracking) task over retention intervals of up to 90 days, but used a much larger number of subjects (96). However, the result intuitively seems suspect, especially since opposite results are found in procedural skills. Youngling, *et al.* also were suspicious of this result, and offered the possible explanation that difficult tasks producing longer or better retention may be an artifact of the measurements of difficulty level.

In view of the inconclusiveness of the above research, it would appear that ease or difficulty of the arc welding task will not have large effects on the results. Similar results will likely be found for somewhat more difficult or more easy continuous control tasks, although more research in this area is needed to confirm any pattern.

2.2.6 Instructional Variations

Studies located in the classroom cannot control variables nearly as well as more clinical studies, but more applicable and perhaps more generalizable results may be attained. One variable that has been researched somewhat for its effect on retention is the method of instruction. If a variety of methods of instruction can be shown to produce similar retention, then generalizability is greater. The converse is true as well. If retention is specific to the method of instruction, then results generalize only to education utilizing similar methods of instruction.

Fleishman & Parker's study [28] asked, among other things, "Is the type of initial training related to retention?" (p.215). They studied retention of a continuous control tracking device that simulated air-borne radar intercept missions using standard aircraft controls. Subjects spent six weeks training in 17 sessions consisting of 21 repetitions of one minute trials. One group learned the task with very minimal instruction, consisting only of the answering of questions, if any. The second group received the same schedule of training but were given instructions, a demonstration of the tracking device, then assistance and three critiques for each subject after trials 7, 11 and 15. The retention interval lengths that were tested for both groups were 9 and 14 months.

The conclusion of this part of the study was that:

> ...differences among our Groups I and II retention samples following periods of no practice of 9 and 14 mo. are a function of *level of proficiency* at the end of initial training rather than the *type* of initial training used in this study [28, p.223].

There was no significant difference between the retention scores of the two groups. While instructional method had an affect on the level of proficiency at the end of the training period, it did not affect retention when level of proficiency was matched between groups. Instructional method affects retention only indirectly, as a function of level of achievement. It would seem justified therefore to generalize the results of the present study across various instructional methods within the subject area.

2.2.7 Length of Retention Interval

Since the significant work of Ebbinghaus [24], many references have been made to the Ebbinghaus 'retention curve', which he derived by learning lists of nonsense syllables then measuring his retention after various lengths of time. The shape of this curve indicates that the rate of memory loss is rapid initially, then decreases as time passes. The applicability of this conclusion to the present study will be considered in more detail in Section 2.3.

The shape of this retention curve may or may not apply to psycho-motor skills, particularly continuous psycho-motor skills. Many researchers [5,12,45,56,61,74] have investigated the effects of the length of the retention interval on skill retention, with quite consistent results indicating a much slower rate of loss than Ebbinghaus' curve indicates.

Fleishman & Parker's research (see Section 2.2.6, page 29) found "...little decrement in performance even for no practice periods of up to 24 months." [28, p.218].

Meyers [63] studied retention of a complex motor-coordination task over five intervals of 10 minutes up to 13 weeks. He also found almost perfect retention over all intervals. McDonald [58] investigated the retention of basic combat skills and found no practically significant decrement of performance. Osborn, *et al.* [70] found no systematic changes in proficiency as a function of time since training, when researching retention of military tank crewman skills. Wilson [107] found that length of no-practice interval produced no significant difference in retention of aircraft pilot skills. Ammons, *et al.* [5] found that performance on a continuous control task (see Section 2.2.2, page 21) actually improved very slightly from 83.4% time on target to 83.5% in the first month of the retention interval, then declined gradually to 76.9% at 2 years.

However, as seen in Section 2.2.5 (page 28), Hammerton [41] argues that when a continuous task is extremely difficult then even this type of task will suffer significant loss, although relearning time is still rapid.

The results are quite different for procedural tasks. Here, time interval has a significant affect on amount of retention. Knerr, *et al.* [50] researched eight procedural tasks over retention periods of up to two years. They found that rapid decay occurs soon after training, with little change in later performance. This result conforms to the classical forgetting curve.

Similar results were found by Schendel, *et al.* [78] in their review of retention of motor skills. They differentiated between procedural and continuous skills in amount of forgetting but found that motor skills in general fit the classical forgetting curve also. However, in reviewing military tasks they concentrated on procedural skills, since most military tasks are broken down into discrete steps.

Naylor and Briggs [66] reached basically the same conclusions as Schendel, *et al.* [78], but added that decrement is specific to task and situation. This may be because each task has a different ratio of procedural and continuous components.

It appears that the classical curve of forgetting that Ebbinghaus first described applies much better to procedural tasks than to continuous tasks. If it does apply to continuous skills it is only over extremely long periods of time. It is possible that, if the retention of continuous skills was studied over a period of 10 or 20 years of no practice, forgetting would be much faster at the start and later level out. Hints of this are seen in the results of studies that have used difficult continuous tasks [12,41] and found that retention was somewhat reduced as a result.

Smith's [89] results seem to deny even this possibility, however. He studied the long term retention of a continuous motor skill, using a pursuitmeter that required the subjects to keep an electronic stylus on a moving electronic bead. Subjects practiced for 12 days, using spaced trials, then retested at 1 month periods over 18 months, then annually for 2 years, and finally after a total of 5 years. He found virtually no loss of skill over the 5 years, and no hints of a classical forgetting curve appeared.

The length of the retention interval does not appear to have a dramatic effect on the retention of continuous psycho-motor skills. From the research reviewed, it may be concluded that the results found in the present study may well generalize to longer or shorter retention intervals. Explanation of the results should not depend on the length of interval, nor does length of interval appear to be required as a variable in the present study.

2.3 Academic Knowledge

This section will deal with studies that have investigated the retention of academic knowledge. These studies fall into two general categories. First, many studies have attempted to establish how much of a certain subject area is retained. These studies are primarily descriptive in nature, and provide some valuable insights into retention of school learning in general. Second, researchers have conducted studies that were more experimental or quasi-experimental as they sought to ascertain the effects of certain variables on the retention of school learning.

2.3.1 Retention of Closely Related Subject Areas

In many ways Industrial Education can be viewed as an applied science. The Metalwork 11 curriculum involves the hands-on solving of problems regarding friction, heat and cooling, expansion and contraction, metallurgy, and a variety of measuring systems involving decimals, fractions, and angles. In addition, problems relating to strengths and weaknesses of materials as well as a variety of introductory design and engineering principles are worked out as a project is manufactured.

Two areas of curricula are most similar to the Industrial Education area. These are Mathematics and Science, in particular Physics, although any laboratory science bears some similarity to Industrial Education. This section will deal first and foremost with the Mathematics and Science areas, and then will briefly review some of the other areas of learning that apply, with varying degrees, to the learning that takes place in the knowledge areas of the Metalwork 11 curriculum.

2.3.1.1 Retention Studies in Mathematics

Two consistent results are often found in retention studies in Mathematics. These are substantial and rapid losses in computational skills, and little loss (and often gains) in problem-solving abilities. This section will review important findings of Mathematics retention studies since the early 1900's.

In 1919, Garfinkle [31] measured the achievement of 747 grade 5, 6, and 7 students. He had three groups of subjects; a 'play' group who did no study or employment work during the summer, a 'work' group that had been employed for at least 4 weeks, and a 'study' group consisting of students that spent the summer at summer school. The retention period was June to September. Garfinkle measured retention in terms of grade equivalents, indicating how much of a "year" a student gained or lost over the course of the summer. While no tests for statistical significance were applied in the study, some results were certainly seen to be of practical significance.

In speed of work, the decrease was never more than one grade. While this is still substantial, the loss of accuracy was greater, averaging the equivalent of almost two years of schooling. Interestingly, the 'work' group generally retained the most; higher even than the 'study' group. It is possible that application of mathematics to 'real life' situations was producing much greater retention than learning in a 'theory only' situation. The present study will explore this possible relationship further.

Thorndike [95], three years later, conducted a study that lends support to Garfinkle's findings, although Thorndike was apparently not aware of them [95, p.625]. Thorndike compared the scores, on a test consisting of five algebra problems, of 189 first year graduate students to the scores of first year college students on a different algebra test. A 40% loss was found. Unfortunately Thorndike made several assumptions that reduce the value of this study. He assumed that the college students' marks would be representative of the marks that the graduate students had received when they entered college. He assumed that the short test administered to the graduate students was equivalent to the algebra section of the Thorndike Intelligence Examination administered to the college students. Thorndike did not report the length of time between college entrance and graduate school entrance, nor the amount of training in algebra during the interval.

The results were, as Thordike stated, "hardly more than hints" [95, p.627]. Their value was in stimulating additional research of a more precise nature, and to open the possibility that the majority of learning was retained, although flaws in the study prohibited any immediate, substantial conclusions.

The following year (1923), Eikenberry [25] tested 18 college seniors in Geometry. These marks were compared with an estimate of high school achievement, as determined by their records of high school grades. This procedure still involved estimates, but slightly more accurate ones than Thorndike's [95] which did not use the same students' marks as a basis upon which to estimate initial levels of learning. Incidental learning was controlled somewhat by excluding any college students who had taken related courses in college. The Minnick Geometry Test A that Eikenberry used measured reasoning ability, not memory of factual or computational course content. Of this ability Eikenberry concluded that 86% was retained. Unfortunately the measures were not likely equivalent, so initial level of learning was only a rough estimate. However, another hint was now available, indicating that reasoning ability in Algebra is retained well.

In the Arithmetic section of her research, Patterson [71] tested 149 children in grades 1 through 8. Tests were given in June and again in September. Haggerty IQ tests were also given at these times. She found that IQ scores improved slightly, while median Arithmetic scores decreased slightly. The loss was minimal, however, ranging from 1% to 4.3%. Of three IQ level groups, the highest group forgot the most, and the lowest group forgot the least.

While Patterson did not do tests of statistical significance, she treated the arithmetic score losses as practically significant. It seems doubtful that such minimal loss has any real significance. No effort was made to assess the reliability of the test instruments [71, p.224].

In 1928, Bruene [19] administered the Stanford Achievement Test to the grades 4, 5, and 6 classes of the University Training School of U.C.L.A. This was done in June and again in September. Expressing the loss or gain as a percentage of a year's achievement, Bruene found that Arithmetic reasoning ability was reduced by only .04 to .1 of a year, while .44 to 1.07 of a year of Arithmetic fundamentals was forgotten. These results show substantially greater loss than do the results found by Patterson [71]. Possibly Patterson's tests measured reasoning, not computation.

Worcester [108] unintentionally compared the retention of Algebra that had been reviewed during the retention interval with the retention of Algebra that had not been reviewed. He administered three forms of the Douglass Algebra test to a small class, using form A-I in February, form A-II in March, then form B-I in May. All tests were repeated in December. Form B-I measured material introduced and covered later in the course, while forms A-I and A-II were "equivalent", covering material introduced early in the school year.

Worcester found that the retests of forms A-I and A-II showed little forgetting (average 80.77% and 84.68% of original scores), and in some cases an increase in scores. However, form B-I showed that students retained only 34.66% of original learning. It is likely that students were reviewing and using the knowledge introduced early in the year, and that this review improved the retention. Material that was not reviewed was quickly lost.

These results confound the effects of a longer retention interval with the effects of an undetermined amount of review. Further, although Worcester points to overlearning as a factor in the higher retention of material introduced early in the year, the average score on the original test A-I was only 46.75%. This would seem to indicate that the material was not overlearned, or, if it was, then the test was measuring something other than what was intended. It may be that review can be beneficial to retention without the material being learned to a mastery level in the process.

In view of the powerful effect of reviews on retention (see results of Gay's [32] research on page 38) only the results of the test B-I can be viewed as reasonably free of confounding variables. Here it may be seen that Algebraic knowledge is largely lost over a period of 6 months of little or no review.

The poor retention shown by test B-I above was confirmed by White [105], who wished to determine which Algebraic skills were best and least retained. She devised a testing instrument which had high reliability measures, and administered it to 139 grade 9 students in June 1926 and then again in September 1926, March 1927, and September 1927. White found that the loss over the summer was 59%, then leveled off at about 77%. White was unhappy with the fact that on each test some students scored 100% and some 0%, and with the fact that some of the problems in the test required many steps that relied on correct responses to the previous step. Because of these problems, White repeated the testing the following year.

For this testing she used an improved test jointly constructed by several Mathematics department heads. In this case she found better retention scores, with summer loss being 32.8%, then 31.5% at 8 months, and then 30.01% at 16 months. However, the 'summer' retention interval lasted to November at which time the study of Geometry had begun. It may well be that Geometry classes included some material that generalized to Algebra. This would also explain the slight improvement that took place at 8 and 16 months.

Although the amount retained appears higher in the second year of testing, both results show large losses of Algebraic knowledge over the summer interval. In 1931, Stokes [92] found similar results, with high school students forgetting about 25% of the material originally learned as measured in June with the Reeve General Mathematics Composite Scale.

A longer retention period was used by Layton [55]. She used the New York State Regents' Examination as the test instrument, administering it to 51 ninth grade algebra students in May, followed by a month's review, then administering it again in June.

The following May, after 11 months of no study of Algebra or related material, the same instrument was used again as a retention test. The average loss of the retention test was 36% of the score on the June pretest.

Schrepel and Laslett [80] found different results when they tested 125 grade 8 students in Arithmetic reasoning and Arithmetic fundamentals, using the Los Angeles Diagnostic Tests in Arithmetic. These tests were administered in late April and then again in early September. There was negligible loss in reasoning, but loss in computation amounted to about 4.5 months of schooling. In view of the fact that students were still receiving Arithmetic instruction from the end of April until some time in June, the loss is even greater than it seems.

A loss of only 10% over the summer was found by Lahey [54] in a study of retention of Algebra fundamentals using 229 grade 9 students. Loss over an additional school year was only approximately 10%. It is possible that students were studying Algebra after the pre-summer test, because it was administered in late May, leaving several weeks of school before the summer break. Instead of a loss, she found a slight gain in problem solving over the year, possibly due to some generalization from the study of Geometry in which the students were participating during the retention interval.

This problem was reduced in the second part of the study which involved grade 9 students. They received the New Stanford Achievement Test at the end of May as opposed to the end of April, thus greatly reducing the amount of instruction received during the retention interval. These students, as could be expected, showed a greater loss on the September computation test, amounting to 7 months of instruction. There was minimal loss in the reasoning aspect of the testing.

In two experiments to determine the effect of reviews and the spacing of reviews, Gay [32] tested a total of 120 Algebra students in grades 7 and 8. Detailed information about the test instrument was not given. The retention interval was 21 days of no instruction. Groups that had one review sometime in the interval lost only 3.4% to 10%, groups with two reviews had a loss of 3.5%, and gains of 9.1% and 13%. The no review groups lost 32% and 51.2%. These results indicate that without review, approximately one third to one half of the Algebra learned is forgotten in only three weeks.

It appears that in the area of Mathematics, losses of factual or computational knowledge are large, even over a short period of less than three months, and as little as three weeks. In their review of school based retention studies Sterrett & Davis conclude:

> It would seem that factual material is readily forgotten whereas concepts and principles are retained with little loss over long periods. [91, p.457]

Douglass makes a similar statement in his early review:

> Investigators differ as to the amount of forgetting, the amounts forgotten within a few months ranging from 10 to 40 or 50%. [23, p.288]

From the results of these various investigations, it appears probable that the factual knowledge area of the Metalwork 11 curriculum will not be retained well. However, some of the factual knowledge is put to use and applied in the practical aspect of the curriculum, while some is not so used. That area of knowledge that is used may be retained to a higher level than is indicated by the preceding studies. The present study will explore this possibility.

2.3.1.2 Retention Studies in Science

The second subject area that should give some indication of the retention that can be expected from the knowledge area of Metalwork 11 is the area of Science. Fortunately, retention studies are available for a variety of laboratory sciences. The results to be seen here, combined with the results seen in the Mathematics area, will act as a foundation on which to build. Studies investigating variables that may impact on this retention of knowledge will be reviewed in Section 2.3.3.

One of the earliest retention studies in Science was that done by Eikenberry [25] in 1923 (see page 35 for a description of this study). Eikenberry had found retention of Mathematics reasoning skills to be approximately 86% of the ability originally obtained approximately 4 years previously. While the original level of learning was only an estimate based on high school marks of the students, Eikenberry's results are consistent with other studies as seen in Section 2.3.1.1.

In the areas of Chemistry and Physics, however, Eikenberry found much greater losses. In Chemistry knowledge, approximately 45% was retained; and in Physics, only approximately 25% of original knowledge was not forgotten. Eikenberry attributes the lack of retention in these areas to "...the fact that the students have had few if any opportunities to apply the knowledge or to review it since leaving high school" [25, p.474]. Taking this idea one step further, the present study will explore the possibility that applying the knowledge *during* high school may improve retention.

Cederstrom [20] measured the achievement of several university Zoology classes at the beginning and the end of the course, and again one year later using the same instruments. He found that 60 to 80% of the gains in knowledge were retained one year later. Although there was no study of Zoology during the retention interval, many of the subjects were pre-medical or pre-dental students who quite possibly took related science courses during the retention year. How much, if any, transfer took place was not determined or estimated. However, Johnson [46] found that only 25.9% of the learning of Botany was retained after 15 months of no study.

In another study of retention of laboratory sciences, Greene [35] wanted to compare the retention of two laboratory sciences (Zoology and Physiological Chemistry) to the retention of a non-laboratory science (Psychology). The test instruments used had relatively high content validity coefficients, but only moderate reliability. This was as low as .55 and the mean reliability was .68. Using 1062 college students, Greene tested in June, then 4 months later after the summer break, then after a total of 8 months, 16 months, and 20 months. In the retention intervals that were longer than 4 months, the possibility of the transfer of course work in other subjects studied became a possible factor in the retention.

After 4 months of no study 55% of the original achievement of Zoology knowledge had been lost, 40% of the Psychology and 40% of the Physiological Chemistry. There was no practical difference in retention among these courses, especially considering the fairly low reliabilities of the test instruments. Long term retention was not available for the Physiological Chemistry students, but in Zoology and Psychology, the amount retained dropped to approximately one tenth to one fifth after 20 months. Forgetting was greatest during the first 4 months in a manner that follows the classical curve of forgetting first demonstrated by Ebbinghaus [24].

Tyler [99] in a study that measured retention of various aspects of college Zoology students tested 82 students at the end of a 15 month interval of no Zoology study. He compared this mark to the marks that these students achieved at the end of the Zoology course. It seems that these two tests were not necessarily equivalent forms or the same test, however, Tyler does not give any test instrument information, nor does he indicate if he suspected any transfer from other courses taken in the 15 month interval.

Loss was substantial in the area of factual knowledge, ranging from 21 to 77% of the gains made during the course. In the areas of applying principles and interpreting new experiments students actually improved from 0.7 to 25%. This pattern of results is consistent with that seen in the area of Mathematics (see Section 2.3.1.1), and with other studies in Science [29,99].

Although he made no effort to determine the amount of study that his subjects undertook during the interval, Walters [103] used the Nelson Biology Test to determine the retention of ninth and tenth grade Biology at the point of graduation from high school. Using 113 students, Walters tested at the end of the original Biology course and again at the end of grade 12 using the same test.

Results showed very high retention, averaging 94%, with little difference between students taking the course in their grade 9 or 10 year. It is quite possible that this high retention reflects the amount of biology studied in the interval years.

In a similar study, Kastrinos [47] used 28 high school biology students, testing them at the end of the course, and then again 2 years later. The posttest was limited to students who did not take biology courses in the interval. He also used the Nelson Biology Test as the test instrument in both testings. A 17% loss of factual material was found to be the result. Kastinos pointed out that this loss was much less than other research [69] indicated, and attributed this to the meaningful, well structured nature of the factual material (Novak [69] had found virtually no retention of the facts learned in Biology after a retention interval of 14 weeks). He also pointed out that teaching involved the principles-critical thinking approach which "...emphasized the principles of biology and ...the interrelationships between the material as the course progressed throughout the year." [47, p.489]

It is equally likely that transfer of general principles and critical thinking ability from related courses taken during the two year interval account at least in part for the high retention. Arzi, Ben-Zvi, & Ganiel [7] found that such transfer of concepts produced gain in knowledge of chemistry facts that were not directly studied in the retention interval (See page 43).

Smeltz [88] found less retention in a study of Chemistry 11 knowledge. He tested

180 students in September at the start of Chemistry 11, then again near the end of the course in May, then administered the posttest in May of the following year. The test instrument was the Anderson Chemistry Test, forms Bm and Am. Smeltz does not state if Chemistry was studied in the interval year.

The items on the test instrument were divided into four categories: factual information, theoretical information, calculations, and applications. Retention was found to be approximately 68% with no statistically significant differences among the four areas. No explanation was offered for the fact that this result differs from other studies [54,80,99] that showed that processes such as application of principles are retained significantly better than factual knowledge.

The retention of the processes of "observation" and "comparison" for students of grades 7 and 8 Chemistry was also shown to be very high by Tomera [96]. Her research used 172 students and retention intervals of 3, 5, and 12 months in which no formal training took place. Retention test scores varied from 88.6% to 110.7% of original learning level. The improvement noted may be an artifact of the test instruments or it may reflect learning and transfer from other areas, formal and informal. The powerful effect on retention of transfer of concepts was shown by Arzi, *et al.*, below.

Arzi, *et al.* [7] conducted a longitudinal study using a large sample of 1176 students, beginning in grade 8 and following them through to grade 10. The sample started with 3167 students, but the attrition rate was high, with the final sample "significantly more competent"(p.174) than the initial group. Students were tested at the end of grade 8 science and again in grade 10, both at the beginning and the end of the course, but measuring different subtopics at different times.

Retention test scores showed gain to 107% of original learning for the topic 'Atoms', and losses to 75% for 'Ions' and 54% for the 'Periodic Table'. These results were in keeping with the frequency of study of related materials in the grade 9 Science course, although these topics were not directly covered in the grade 9.

> ...concepts related to the subject ATOM are included and more frequently used than concepts related to IONS, but principles of chemical classification, which are inherent to the Periodic Table, are absent. [7, p.182-183]

Apparently when transfer from related topics is minimal, retention of the factual knowledge of Chemistry is approximately 54% as measured by Arzi, *et al.* [7].

Reviewing retention of high school science, Sterrett & Davis conclude that:

> ...high-school seniors showed a forty-two per cent loss of informational material after a period of three months. After a five-year period college students were able to recall approximately nineteen per cent of the informational material studied in high-school chemistry. [91, p.456]

Overall it seems that laboratory science knowledge is retained approximately to the same extent as Mathematics. Retention is substantially increased if knowledge is used or related to principles and concepts. As in Mathematics, concepts are retained much better than is factual knowledge.

From the results of research reviewed in Sections 2.3.1.1 and 2.3.1.2, it appears that the factual knowledge of the Metalwork 11 curriculum should suffer substantial loss over a retention period of approximately three months. The research also indicates the possibility that retention of this factual knowledge will be enhanced if it is related to or used in the application of principles or concepts. The present study intends to explore the possibility that using factual knowledge in the development of psycho-motor skills will also produce increased retention.

2.3.2 Retention of Other Subjects

Several studies have researched the retention of the areas of Reading, History, and Languages. Most of these studies were done prior to 1940. Many of them do not involve the exploration of effects of different variables, but rather seek to find out how much of actual classroom learning, in typical settings, is retained after periods of a few months up to a year.

These studies will not be reviewed in great detail, but an overview may help to complete the picture of retention of the knowledge area of school curricula.

2.3.2.1 Reading

Four studies [19,26,65,71] used standardized tests to measure reading ability of elementary school students before and after the summer.

Bruene [19] studied grades 4, 5, and 6, using the Stanford Achievement Test form A in May and form B in September. She found that the mean change was a gain of .06 of a year's work, compared to a mean loss of .44 of a year's achievement in Arithmetic (see page 35).

Elder [26] found an even greater gain using Monroe's Standardized Silent Reading Test forms 1 and 2 over the same retention period. Grades 3 to 6 averaged a gain of .45 of a year's achievement. In this case it would appear that the students learned faster out of school than in school.

More modest gains were found by Morgan [65], who found grade 6 students gained 1% to 4% over the summer. Here Thorndike-McCall's Reading Scale was used in June and September.

The fourth study, done by Patterson [71] showed that students in grades 4 to 8 ranged in retention of reading from a 5.6% loss to a 1.7% gain. This research also used

Thorndike-McCall's Reading Scale to measure retention over the summer break (see page 35 for additional information regarding this study).

Similar results were found by other researchers [43,53]. However, in no case was an effort made to ascertain the amount of reading done in the summer months, nor are studies available to see if the same pattern holds true for secondary school students.

Two other studies [8,106], investigating how much knowledge of materials that are read is retained, found considerably less retention. This is a substantially different type of retention than is retention of reading ability.

Austin's [8] subjects were mature adults who read technical passages and then were measured on their knowledge of the content of the passages. The testing was repeated at 2 and 4 weeks. Depending on the timing of the learning sessions the subjects retained 25% to 42% of the material after 4 weeks.

Using limited learning time, Whitely & McGeoch [106] found that retention of poetry was very limited over about 4 months. College students were given 15 minutes to read a short passage of poetry, then were asked to write down all that they could remember. This exercise in memory was repeated after 15, 30, 60, 90, and 120 days, with retention being reduced from 64% at 15 days to 29% after 120 days. Different groups were used for each of the retention intervals.

While reading ability seems little impaired and often improved, after a period of approximately 3 months, the retention of the content of the material being read decreases rapidly. This pattern is analogous to the retention of factual content versus the concepts and principles of Mathematics and Science. It may be that the ability to read consists of the retention of various principles and patterns, or it may be that reading is done so often that there was no such thing as a no-practice interval for the students involved in the studies. In either case it is very possible that the high retention of reading ability does not present a result substantially different from that found in the studies of Mathematics and Science retention.

2.3.2.2 History

A few studies have been conducted to investigate the retention of historical material. The results of this research do not add a great amount to what has been found in the areas of Mathematics, Science, and Reading, but some implications of the studies are of interest.

Fairly high levels of retention of American History were found by Bassett [11]and Brooks & Bassett [18]. These studies found retention levels of 87% after 4 months and 69 to 72% after 16 months. Eikenberry found higher levels of retention, and even gain, in American History (95 to 125%), although flaws in his study have been noted (see page 35).

These results are contradicted by the results of Van Waganen's study [101] researching retention of American and World History. Using 800 first-year university students as a sample, Van Wagenen tested these students with the same test that grade 8 history students write. He concluded very few university students could obtain a grade higher than the average grade 8 student. The retention interval since the university students' last history course was 1 or 2 years. However, by using different groups for the pretest and the posttest, and by less than rigid controls on study during the interval, Van Wagenen's study leaves firm conclusions unavailable.

An explanation for the generally high retention of history (excepting Van Wagenen) can be seen from Ellis' [27] research into the retention of learning of World History. Ellis compared the scores of 417 college students with the means of high-school students writing the same test. He found very little loss over the 2 or 3 years between high-school and college. Ellis went further and compared the scores on the retention test of students who had taken no history courses, one history course, or two history courses.

He found a statistically significant difference among the groups, but it was too small to be of practical difference. Students with no course in World History attained a mean score that was 80% of that attained by students with two courses, and 90% of that attained by students with one course in World History.

Ellis concluded that incidental learning of World and American History must form a large part of the historical knowledge of college students. He does not indicate whether he was measuring the retention of concepts or factual knowledge.

The indications are that incidental learning in American and World History is high, and that this has a substantial effect on the amount retained. It is evident that studies into retention over long periods need to consider incidental learning, and if possible ascertain the amount of this learning that took place during the retention interval.

The skills and related knowledge taught in Metalwork 11 are of a nature that the possibility of incidental learning during the retention interval is high, even though little formal schooling will take place during the interval in the present study. This possibility will be investigated by means of a questionnaire at the end of the retention interval.

2.3.2.3 Languages

Kennedy [49] found 66 to 85% retention of principles of Latin syntax after a summer interval of no study. He tested high school students using the Pressey test in June and again in September. After one year, retention was 54% to 68%. Schmidt [79] found somewhat poorer retention of Latin vocabulary by grade 6, 7, and 8 students. He found a 76% retention of the English meaning after 4 weeks and 57% after 3 months.

Anderson & Jordan [6] divided Latin vocabulary into three groups: vocabulary with almost identical English equivalents, vocabulary with somewhat similar English derivations, and vocabulary with no apparent connection with the English translation.

Two flaws detract from Anderson & Jordan's work. First, the amount of time allowed for the test was only sufficient for 50% of the sample to complete the test. Second, some of the subjects did not understand the meaning of the English words used as the equivalents. If only 50% of the subjects knew the meaning of a given English equivalent, Anderson & Jordan used the word in the test. Thus it is possible that some English words were not known by a large group of the subjects. These two flaws make any conclusions suspect if they are drawn from this study alone.

Nevertheless, Anderson & Jordan found that after 8 weeks, grade 7 students had a 56% retention of original learning of the translations for the 'no similarity' words, 73% for the 'somewhat similar' words, and 97% for the 'almost identical' words.

It would appear that retention of languages follow the same pattern of retention found in the areas of Mathematics and Sciences, with retention of factual knowledge being lower than that of principles.

Bahrick's [10] 1984 study of the memory of Spanish learned in school is one of the most significant contributions to the study of academic knowledge retention. He used retention intervals of 1 to 50 years, with a sample size of 733 people. These were divided into groups based on amount of Spanish studied and length of time since that study ceased. One group of 40 subjects had no training in Spanish. There was a low level of incidental learning. Rehearsal during the interval was also minimal, with no significant rehearsal effects being found.

A retention test that measured various types of Spanish language recall was constructed and administered. Original learning was assessed on the basis of a questionnaire. Information given on this questionnaire was verified for 14% of the subjects. It was found that 81% of the subjects correctly stated the number of Spanish courses taken, and 96% of the subjects placed themselves in the correct retention interval group. Ninety-seven percent reported grades on these courses within .5 of the verified average. Interestingly, the accuracy of reporting of this information did not decline with the time interval.

At one year, subjects retained between 65% and 95% of their original learning. Retention differed with the 10 dependent variables, which were different aspects of Spanish learning (e.g., grammar recall, reading comprehension). At 50 years retention was still fairly high, ranging from 25% for grammar recall to approximately 70% for Spanish-English vocabulary recognition. This is partly an artifact of the measurement system, with recognition being a more sensitive measure of retention than recall [33].

Bahrick explains the very long term retention with a special memory state called "permastore" (p.22). Responses that have been retained over many years must have been in this state initially. There is, however, another explanation that is better supported by the general body of research. Neisser [67] cites Loftus & Loftus [57] arguing that "The widely held belief in permanent storage of specific experiences has essentially no basis in fact" [67, p.33]. He further argues that:

> Information that is tied into an extensive and redundant cognitive structure (to put it another way: information that specifies an extensive and redundant external structure) is sharply resistant to forgetting; isolated pieces of information, in contrast, are much more vulnerable. [67, p.34]

The isolated pieces of learning disappear, accounting for the loss in the first few months or years. The knowledge that has been tied to the concepts and principles of the Spanish language is that knowledge which is relatively permanent. Bower, after interviewing Bahrick, wrote:

> Students develop a "cognitive structure" or "schema" for Spanish, he [Bahrick] notes. When retested years later, they use this general knowledge to generate correct responses rather than dredging up specific memories from permastore. [15, p.149]

Bahrick's research is considerably better controlled than many previous studies of the retention of academic learning. However, although he explains his results in terms of 'permastore' it is probable that his results fit better into the pattern of retention seen in most other retention research. Cognitive structures, principles and concepts are retained well over long periods, while factual knowledge is lost relatively quickly.

2.3.2.4 Word Lists

The much greater loss of factual knowledge, as compared to cognitive structures, is clearly seen when factual knowledge is almost completely disassociated from supporting concepts and principles. This is generally done with word lists, nonsense syllables, or paired associates.

The early study of Ebbinghaus [24] is a good example of the retention found for the recall of nonsense syllables. Retention was measured by relearning, expressed in terms of percent of original time to learn the syllables to the criteria of of one perfect reproduction. After 19 minutes, relearning time was 41.8% of the time it took to learn originally. After 24 hours relearning time was 66.7%, and after 39 days relearning time was 78.9% of original learning time.

Rapid initial loss continuing until the majority of the material is lost was also the conclusion of Shuell & Keppel's study [83]. They used lists of nouns committed to memory by grade 5 students. After a retention period of 24 hours, 50% to 55% of original learning remained. This decreased to 45% at 48 hours. Allen, Mahler, & Estes [3] also found high rates of forgetting of paired associates, unless practice trials were conducted during the interval.

Studies in this section were conducted in clinical settings. Detailed review of the many studies conducted in this manner is beyond the scope of this paper since such studies have limited generalizability to the 'real life' situation of the present study.

However, these studies of the retention of non-meaningful material show that retention of material that is of little meaning to the subject is retained very poorly.

Sections 2.3.1 and 2.3.2 have reviewed research investigating the amount of retention of various academic subject areas. Losses over intervals of approximately 3 months have been substantial in the area of factual knowledge, often 20% to 40%. In the areas of application, concepts, and principles, retention has been higher, with little or no loss over retention periods of approximately three months and often longer.

Where factual knowledge can be closely tied to the principles and structures of the topic, then retention of this factual knowledge increases. Although no studies are available that measure retention levels of Industrial Education courses, the consistency of the results in other subject areas allow tentative generalization to the area of Industrial Education. It seems probable that factual knowledge in Industrial Education and Metalwork 11 specifically will show significant loss over a three month period of no study.

In Metalwork 11 much of the factual knowledge is not left in isolation, but is applied and used in the development of psycho-motor skills. It is possible that this area of knowledge will be retained to a higher level than that knowledge which is not so used. The use of factual knowledge in the development of a psycho-motor skill may link that knowledge with a broader framework of concepts.

2.3.3 Variables in the Retention of Academic Learning

The effects of several variables applicable to the present study have been researched in the past. This section will deal with each of these variables and their effect on retention. The foundation that these results provide for the present study will be briefly noted in each case.

2.3.3.1 Initial Learning Level

Section 2.2.1 reviewed literature investigating the effects of amount of initial learning in the retention of psycho-motor skills. The general pattern of results was that amount of initial training had a positive effect on retention, not just in absolute amounts, but also in percentage of initial skill retained [5].

The effects of initial learning level on retention are not as pronounced in the area of academic learning. This section will review the results of studies that have used initial learning level as a variable in retention of academic learning.

Studying the amount of knowledge of American history retained by 495 grade 7 and 8 students, Brooks & Bassett [18] found that after intervals of 4 to 16 months, students that obtained the highest level of learning also forgot the most. However, relative standings remained little changed. Students who forgot the most also retained the most.

The same results were found by Cederstrom [20]. He researched the retention of three classes of college zoology over a 1 year period. One of the results noted was that:

> Percentages of retention have but little relation to amounts of gain but the amounts of retention are proportionate to amounts of gain. [20, p.520]

Smeltz [88] found that the correlation between achievement and retention was .79, while the correlation between IQ scores and retention was only .39. He studied the retention of 180 grade 11 Chemistry students over a 1 year interval (see page 42).

Romberg & Shepler [75] studied a relatively small number (25) of grade 6 students to investigate retention of probability concepts and knowledge. They also checked correlation between level of achievement and retention and found it to be .78, almost exactly the correlation that Smeltz had found a few years earlier using older students.

A study done by Kurtz [52] found that upon dividing the scores of the 343 students into quartiles, "the more a student knew at the end of 4th grade, the more he forgot during the vacation" (p. 67-68). However, the percentage of loss remained quite constant for the top three quartiles (22%, 22.5%, and 20.2%) and dropped dramatically only for the bottom quartile (4%).

The long-term study done by Bahrick [10] (see page 49) indicated that over shorter periods of time, perhaps up to a year, retention as a percentage of initial learning remained quite constant, although absolute loss was greater for those with higher initial levels of achievement. When the retention interval grew longer, however, the effects of this constant absolute loss had increasingly more importance. For example, after 5 years, the level of English-Spanish recall dropped from a score of 12 to a score of 0 for those with a lesser level of training. The group with moderate training dropped from 17 to 6, and the higher trained group dropped from 22 to 11. The absolute amounts of loss was a score of 11 or 12 in each case, but percentage loss was 100%, 65%, and 50% respectively. The shorter the retention interval is, the less likely one is to see dramatic percentages of loss.

As in the area of psycho-motor skills, the retention of academic learning is strongly and positively correlated with the initial level of achievement. While there are differences between and within these two areas in terms of absolute loss compared with relative loss, it is clear that if more is learned, more is retained. It seems that over longer periods of time, a clear difference in percentage of learning retained also results.

The present study will explore the effects of mastery level learning of academic knowledge to that of non-mastery level learning. Interactions between this effect and the effect of use of the knowledge in development of psycho-motor skills will also be investigated.

2.3.3.2 IQ and Ability Measures

Intelligence measures will not be used as a variable in the present study. Several past studies have explored the relationship between the scores derived from intelligence measures, and the degree of retention. The results have been unanimous. No practically significant correlational relationship has been found between IQ measures and retention. A brief review will substantiate this.

Patterson [71] divided 149 elementary school children into three groups based on their scores on the Haggerty Intelligence Examination. She found no clear pattern between retention and IQ scores. Statistical tests were not conducted, but the data indicate no practical differences (see page 35 for a description of this study).

Although the flaws of his study have been noted (see page 36), one of the values of Worcester's study [108] is that it adds to the body of research that finds retention to be unrelated to IQ. Kennedy [49] also agreed, stating that:

> ...in general, intelligence is not a significant factor in the remembrance of Latin syntax over the summer vacation. (p.137)

Kolberg [51] studied the retention of American History subject matter, using grade 8 students as subjects. The Terman Group Test of Mental Ability was used to obtain a score of mental ability. After the summer vacation retention period, Kolberg found that the correlation between retention and intelligence was only .19. This low coefficient was correctly interpreted by Kolberg as meaning that "...pupils with high intelligence may forget as much as pupils with low or average intelligence ..." (p.283).

A slightly higher correlation coefficient was found by Smeltz [88], who determined that retention was correlated to IQ at a level of .39. His study involving the retention of Chemistry knowledge over 1 year by high school students is reviewed in Section 2.3.1.2.

Walters [103] also found no practical correlation between retention of science subject matter and IQ scores (see page 42 for a summary of Walters' study).

The dissenting voices in this area of research belong to Anderson and Jordan [6]. In their study of retention of the meanings of Latin words, they found what they termed a "high" degree of correlation (page 494) between retention and IQ scores. However, the calculated coefficient was .59, which is not particularly high. Further, serious flaws in their testing procedure and test construction leave even this moderate correlation in doubt (see page 48).

There appears to be little value in further investigations of correlations between IQ scores and retention.

2.3.3.3 Use or Application of Knowledge

It has been shown that the retention of subject matter by students is often very low. Several researchers of retention of school subject matter have speculated about the possible effect that use or application of knowledge might have on retention. However, little research exists to confirm or deny these speculations.

As early as 1923, Eikenberry [25] suggested that the reason that his 34 college students retained more American history content than Physics or Chemistry content could be:

> ...that the students have had few if any opportunities to apply the knowledge or to review it since leaving high school... Pupils too often do not learn the relationship between the facts of science and the world about them and as a consequence the larger part of the facts once known soon fade away. (p.474)

Bruene [19] studied retention of arithmetic computation skills of elementary school students over the summer recess. She speculated that:

> ...it is possible that the drill that is given is not practical, that is, it is not what the children actually use. (p.312)

Industrial Education courses tend to emphasize the use of subject area content. Students apply much of the knowledge that is introduced, with the use of the knowledge often being explored immediately after the acquisition of the subject matter content. Although no research exists to measure the effect of this application on retention, some related research does exist to shed tentative light on the topic.

Travis & White [97] conducted two studies to determine if enacting a brief story would improve the retention of elements of that story. Thirty-five children were selected from three kindergarten classes. Two groups were formed, with one group enacting the story with puppets, and the other merely listening. In a second study, two more groups were formed. Group 3 children listened to the story, then were told to close their eyes and imagine the story happening. The fourth group watched the experimenter enact the story with a puppet while the children listened to the narration.

Post-testing was done 30 seconds after completion of the story, then again one week later. Testing was done verbally and individually, following a guide that broke the story down into 14 categories, with each category containing both explicit and implicit information items.

The study found that the children who enacted the story with puppets "recalled significantly more story elements and explicit information than all other groups" (p.137). This group also retained significantly more explicit and implicit information and story elements than the 'listen only' group. Travis & White concluded that:

> ...the evidence suggests that varying the manner in which children interact with narrative material affects their recall performance of that material and

> that motoric organization of the narrative information yields significantly higher recall rates. (p.145)

A similar study was carried out by Moody, Abell, & Bausell [64]. They studied the retention and transfer of multiplication skills of grade 3 students after 6 and 8 weeks of no instruction. Ninety students formed the sample. One group received activity oriented instruction in which instructional materials were manipulated by the students, another group received primarily expository instruction, a third received expository instruction plus practice in word problems, and the fourth group acted as the control group receiving normal instruction in arithmetic but avoiding multiplication altogether.

No significant differences were found among the groups. Unfortunately the degree of initial learning of the multiplication skill was low, and the authors pointed to this as a flaw in the study that may well explain the lack of significant differences in retention. Studies examined in Section 2.3.3.1 indicate that level of initial learning has a substantial effect on retention (see page 54). It appears probable that the explanation presented by Moody, *et al.* [64] is accurate.

Simulation games also provide a means of using knowledge gained in the classroom. While little motor involvement is required, application is present in a situation that provides simulation of a more true-to-life setting than is available in an expository setting.

Again, little research is available that measures the effect of this type of learning on retention. Pointing this out, Cohen & Bradley [21] sought to explore possible effects of simulation games on the retention of map reading concepts and skills.

The sample was made up of the grade 5 and 6 classes of two schools in Kansas, totaling 8 classes. Teachers of the control group taught map reading skills and concepts in their usual way without using simulation games. The experimental group was encouraged to actively participate in the game. The posttest and the retention test two weeks later used the same instruments, namely the Iowa Test of Basic Skills and the Concept Development Test.

There was no significant difference in the mean scores of the two groups immediately following the instructional period, but two weeks later the experimental group's scores on map reading skills had improved from 16.82 to 17.58, while the control group had loss from 16.19 to 15.59. This was a statistically significant difference at the .05 level of significance. There was no statistically significant difference in the retention of concepts.

There is, however, an alternate explanation for the improved retention. It may not have been the application of skills in a simulation of real life, but rather the "enjoyable change of pace" [21, p.252] that simulation games provide may have prompted greater interest for a short period of time.

The results of these studies may not generalize to the older students of Metalwork 11. Also, the subject matter studied may not be sufficiently similar to the knowledge area of Metalwork 11 to allow generalization. The use of knowledge in Metalwork 11 consists of the application of this knowledge in the development of psycho-motor skills typical to the metalworking industry. Studies discussed in this section did not use knowledge in this way. These studies provide hints only as to the possible pattern of retention of used and unused knowledge in Metalwork 11.

These hints, however, do point in the direction of improved retention for knowledge that is used and applied in some way, as opposed to knowledge that is not so used, and is often quickly forgotten. This study will attempt to provide evidence regarding the retention of used and unused knowledge in the Metalwork 11 curriculum.

2.4 Skill versus Verbal Learning

It is very difficult to make a direct comparison of the level of retention of skill learning (activity based) versus the retention of academic learning (verbal based). Several things appear impossible to equate.

First, the degree of initial learning is not directly comparable. The criterion of one perfect trial in a psycho-motor skill may not be equal to one perfect trial in the recall of a technical article. There is no way to answer this difficulty satisfactorily.

Second, the systems of measurement of retention are, of necessity, different for psycho-motor skill and academic learning. Academic learning is often measured with a pencil and paper test, while psycho-motor skills are often measured by some performance rating inventory or scale. Fifty percent on one may not equal 50% on the other. Thus direct comparison of scores is not possible.

Third, level of difficulty is very hard to equate. It is probable that the difficulty of one sample of skill learning is different from the difficulty level of a given sample of academic learning.

These are the three most important problems standing in the way of direct comparison. Other confounding variables, such as degree of task organization, also exist.

Despite these difficulties, some attempts have been made to determine if skills are retained to a greater or lesser degree than verbal learning. Intuitively, the retention of continuous skills (section 2.2) should be greater than retention of academic learning (section 2.3). Studies directed at backing up this conclusion have run into difficulties.

Leavitt & Schlosberg [56] examined the retention of nonsense syllables and pursuit rotor performance over periods up to 70 days. Their results showed better retention for the motor skills. Motor skills increased over the retention interval while verbal learning decreased.

Problems in this study were that retention of nonsense syllables is very poor because of the meaninglessness of those syllables. Motor skills are possibly much more meaningful, with one action a natural result of the previous action. Further, it appears that motor skills were experiencing practice effects due to the testing. Whether or not verbal learning was affected to the same degree by recall tests is unknown.

In an attempt to control for difficulty of task, McGeoch & Melton [59] used a stylus maze task and learning of nonsense syllables. Three levels of difficulty were used for each type of learning. Each task was learned to the criterion of one correct trial.

After the retention period of one week, no clear pattern emerged. One type of task was retained to a greater degree at one level of difficulty, and the other task was retained better at a different level of difficulty. However, as Adams has pointed out:

> Moves through a maze can be covertly encoded as "left, left, right, left", and so on, or in some higher order way. [2, p.45]

The maze task was possibly not a good example of a psycho-motor skill, leaving the results in doubt.

To try to more accurately equate psycho-motor skills and verbal learning, Van Dusen & Schlosberg [100] attempted to equate task organization of the two types of learning. They found that retention was equal under these circumstances after intervals of up to 28 days. But here there were difficulties as well.

The task that was used as a sample of psycho-motor skill was procedural, which has been known to have large verbal learning components [68]. Thus Van Dusen & Schlosberg were, to some extent, comparing verbal learning with verbal learning, and finding retention patterns very similar. Further, there is no certain method of equating organization of psycho-motor skills with organization of verbal learning. The verbal learning aspect of a procedural skill does help to allow equating of task organization, but causes other problems as noted.

One other study [104] was done in the area of emergency medicine, to evaluate the retention of life-saving skills and knowledge. This study did not intend to make a direct comparison between the retention of technical skills and cognitive knowledge in general, but rather to determine which areas of learning were retained and which were lost after a given period. It does, however, give hints as to the possible outcome of the present study and, as such, does add to the foundation that the present study is built upon.

Weaver, Ramirez, Dorfman, & Raizner [104] studied 61 people who had been trained in a 4 hour basic life support course. This course included both appropriate cognitive information and psycho-motor skills. The subjects were tested after 6 months of no practice, using the same measuring instruments that were administered at the end of the course.

The cognitive test instrument consisted of multiple choice items, while the psycho-motor test was a performance rating scale consisting of 12 aspects of the skill; the first 8 were procedural, and the last 4 measured continuous skills.

Overall, the results showed a retention rate of 87% of original learning in the cognitive knowledge area. The procedural aspect of the psycho-motor skills component was retained at a level of 63% of original learning, but the continuous skills actually improved. Retention scores here were 110% of initial scores. Whether this gain was because of transfer of learning from related skills over the retention interval, or because of practice effect caused by the testing, is unsure. However, learning or practice in the interval was controlled for. It is most probable that the end of course testing constituted a practice session, and that 6 months of no practice was not enough time to cause significant decrement in skill level.

These studies have either not used a 'real life' sample of psycho-motor and verbal learning, but have rather used nonsense syllable learning, [56,59] or they have used a psycho-motor skill that may have a large verbal learning component [59,100]. As a result, no clear pattern emerges from the review of these studies.

The study that was conducted under true-to-life circumstances [104] found that the retention of continuous skills was substantially greater than academic knowledge. However, the reasons for this superiority are uncertain. Attempts to isolate variables such as difficulty [59] and task organization [100] have not been successful.

Few gains seem to have been attained since Thorndike's suggestion that motor skills seemed to have some intrinsic quality that rendered them more resistant to forgetting than verbal skills [94, p.327].

The present study will deal with retention of continuous psycho-motor skills in the classroom setting, and make tentative comparisons of this retention with that of learning of academic knowledge. This academic knowledge will be meaningful knowledge as opposed to nonsense syllables.

2.4.1 Summary

The research reviewed in this chapter provides a foundation for the present study. Although not obtained from samples equivalent to the sample of the present study, several overall results are apparent in the area of retention of psycho-motor skills and academic knowledge.

In the area of psycho-motor skills, higher amounts of initial training produced significantly higher retention rates, as did spacing the practice sessions as opposed to massing or condensing them. Varying the amount of practice of the skill during the retention interval did not produce consistent retention effects. Varying the length of the retention interval, or the type of instruction given produced no significant retention effects.

In the area of academic knowledge, concepts, structures, and principles are retained relatively well, but factual knowledge is not. If initial learning level is high, loss becomes greater, but more is still retained than is the case when initial learning level is lower. IQ scores are not highly correlated with retention, and this result is consistent across many studies. However, use of knowledge in an activity based learning situation improves the retention of the knowledge.

Comparison of retention of psycho-motor skills and factual knowledge is difficult, due to problems in equating variables across two types of learning.

The present study will consider several variables introduced in this chapter, applying them to the Metalwork 11 curriculum. Use of knowledge, and initial level of learning will be of special interest.

Chapter 3

Methodology

3.1 Overview

This study seeks to determine the relative retention rates of three main areas of the Metalwork 11 curriculum:

1. Psycho-motor skills;
2. Knowledge used in the development of psycho-motor skills;
3. Knowledge not used in the development of psycho-motor skills.

Several other variables, as discussed in Chapter 1, will be considered in order to offer possible explanations of any retention patterns that are found (See Section 3.4, page 85 for a list of variables and grouping factors).

In order to determine retention rates in these three areas of the Metalwork 11 curriculum, tests were administered to a single Metalwork 11 class in June of 1988. The same tests were administered to the same class in September of 1988. These tests measured various areas and variables that were pertinent to the study.

3.2 Sample

A sample of 22 senior Metalwork students was chosen for this study. They began participation in the study in their Metalwork 11 year, and ended with the completion of the study in the initial weeks of their Metalwork 12 course. This sample consisted of the Metalwork 11 students who went on to enroll in Metalwork 12.

The study began with all Metalwork 11 students in a school of about 800 students. These 31 students formed two classes, each receiving the same instruction, from the same instructor (the researcher). It was to these students that the pretests were administered. Not all of the 31 students were expected to continue on to Metalwork 12 since, due to the 'real life' situation of the study, it was recognized that some students would not elect to continue the study of Metalworking into grade 12.

A second cause of attrition was that some of the students in Metalwork 11 actually had two years left until their graduation, so a few would have to wait another year until they could enter Metalwork 12. This is because demand for the course exceeded the available teacher and classroom time available, necessitating the restriction of Metalwork 12 to those students who were in their graduating year.

Primarily for these two reasons, the retest was administered to a reduced sample of 22, which was the number of students enrolling in Metalwork 12. These students were all grade 12 males.

3.3 Instrument Construction

To measure the retention of knowledge and skills in Metalwork 11, two instruments were developed. One was designed to measure the two areas of factual knowledge (knowledge used and knowledge not used in skill development). The second was in the form of a "hands on" demonstration of a psycho-motor skill that was largely continuous, namely an arc welding skill.

3.3.1 Norm versus Criterion Referenced Measurement

Criterion referenced measurement is intended to determine mastery or non-mastery of a specific performance criterion. For example, an educator may want to determine if a student can correctly add two digit numbers. A criterion referenced measuring instrument would be intended to provide the evaluator with a 'yes' or 'no' answer to this or another question regarding a "very precisely defined content area" [14, p.288]. If broader content areas are to be measured, then several test instruments would be used, each to measure a specific part of the broader total.

Measurement of this type does not, and is not intended to, provide fine distinctions in degree of learning of the performance. It is often used to provide diagnostic or placement information.

Norm referenced measurement is concerned with the relative achievement of students. The intention is to detect even small differences in achievement of individuals. Norm referenced testing allows comparison of the achievement of different groups, generally in a given subject area such as fifth-grade science.

The present study intends to explore the possibility that differences exist in Metalwork achievement scores from June to September. To do this, the type of measurement that is appropriate is norm referenced measurement.

Where criterion referenced measuring instruments require items that reflect the difficulty of the performance being measured, norm referenced testing requires items that discriminate well.

> ...a key feature in constructing norm-referenced tests is the selection of test items that provide a wide range of scores. This is done by eliminating those items that all pupils are likely to answer correctly and by favoring items at the 50 per cent level of difficulty. Such items tend to maximize

differences in performance ... [36, p.20]

Considerations relating to norm-referenced measurement guided analysis and selection of the items that made up knowledge measuring instrument.

3.3.2 Development of the Knowledge Instrument

This section will discuss the method used to develop a test instrument that could reliably measure the knowledge area of the Metalwork 11 curriculum. The measures of validity and reliability that were used will also be reported, along with the results of these measures. A later section (Section 3.3.3) will deal with the development of an instrument to measure a psycho-motor skill.

3.3.2.1 Item Type

The instrument that was used to measure knowledge areas was constructed using multiple choice items. This type of test item was chosen over constructed response items for several reasons.

The multiple-choice item is applicable in the measurement of a wide variety of areas of achievement. It is also free of many of the limitations of other forms of objective items. It tends to present a more well-defined problem than the short-answer item, it avoids the need for homogeneous material required by the matching item, and it reduces the clues and susceptibility to guessing that are characteristic of the true-false item. In addition, the multiple-choice item is relatively free from response sets and is useful in diagnosis. Its limitations derive mainly from the fact that it is a selection-type paper-and-pencil test. [36, p.199]

Allen and Yen [4] doubt the accuracy of the criticism by some evaluators who feel that multiple-choice items restrict measurement to set responses and superficial learning outcomes. Allen and Yen argue rather that:

> ...carefully constructed multiple-choice items can measure complex thought processes, comprehension of nuances of meaning, and creativity. [4, p.120]

Multiple choice items are easy to score and analyze by computer, as programs are readily available to do detailed analysis, providing the researcher with detailed information on each distractor, item, and the total test.

Although the multiple choice item is difficult and time consuming to construct, the benefits were judged to be worth the effort.

3.3.2.2 Item Collection

The first step in developing the test instrument was to outline each topic in the senior Metalwork courses' curricula (Metalwork 11 and Metalwork 12A & 12B). This was done using the British Columbia Ministry of Education Curriculum Guide [17], and adding or deleting a few learning outcomes to more closely reflect the curricula as implemented in the study situation. The school district used in the study has a largely rural population of approximately 25,000. Economically, the community is primarily dependent on the lumber industry, with many people employed as independent owner/operators of logging equipment. Over the past thirty years a very strong Metalworking program has evolved to suit the needs and interests of the students of this community. Thus some aspects of the Ministry's guide have been changed either in substance or in implementation. These changes, although minor, were reflected in the outline prepared for the purposes of developing the test instrument.

The curricula were then divided up into 20 topical areas for the purposes of organizing a bank of items. The next task was to collect a sufficiently large bank of available questions to allow adequate measurement of the intended learning outcomes. Three item sources were used. Two sources consisted of banks of questions, developed by two experienced Industrial Education teachers over the years of their teaching. The third consisted of the construction of new items to fill in the gaps in the curriculum outline that were not covered by items in the available banks. When items existed to adequately sample the learning outcomes of each topic in the curriculum outline, construction and collection ceased. The bank finally numbered approximately 500 items.

3.3.2.3 Item Piloting

Each item was then scrutinized for its validity specifically to the Metalwork 11 curriculum. Three hundred items that best applied to the course as taught during the year of test construction were piloted. These items were piloted at least once and often two or three times, in one or more of five classes. Two of the classes were the Metalwork 11 classes that were to be studied at the end of the year. Another two classes were Metalwork 12 classes, one at the same school as the sample groups, and the other at a similar school that operated a similar program in the same city. (The Metalwork 12 courses at the two schools were co-operatively planned). The fifth class that was involved in pilot testing was a previous Metalwork 11 class whose year-end test data was analyzed.

The items that had been analyzed were divided into four groups based on the statistical analysis of the pilot test result. The statistics that were used in this preliminary rating were the proportion endorsing the correct choice, and the point biserial correlation for each response, which correlates the rank positions of the students with their choice of endorsing or not endorsing each distractor.

3.3.2.4 Item Selection Criteria

In order for a question to pass the first pilot testing with a 'good' rating an item needed to have a correct response proportion of between 30% and 70%, as well as a positive point biserial correlation coefficient on the correct response and negative point biserials on each of the distractors. Exceptions were made when a distractor had a slightly positive point biserial but only one to three students endorsed the distractor.

A secondary category ('fair') was set up for questions that were to be used if more items were needed to fill out the second piloting. These items had the same analysis results as did the 'good' items, but had a slightly broader acceptance tolerance in terms of proportion of students choosing the best answer. This ranged from 20% to 80% for the 'fair' rating. Items that did not meet the criteria above were rated 'poor' and were not used any further.

One of the variables that was to provide information about the retention patterns was the variable of level of initial learning. Thus the retention of especially well learned topics was to be measured.

For this reason a fourth category was created for those questions that had point biserial scores that were desirable (as the 'good' and 'fair' items) but had a proportion endorsing the correct response of over 70%. These items were to be used to help determine if group mastery learning produced a significantly higher rate of retention than did group non-mastery learning.

This analysis produced approximately 130 'good' items, 130 'poor' items, 40 'fair' items and 60 'group mastery' items. A large test was made up of most of the 'good' items, a small number of the 'fair' items, and about one half of the 'group mastery' items. This new large test totaled 150 questions.

The retention rates of two areas of the Metalwork 11 curriculum were to be measured using the multiple-choice instrument. One, the instrument measured the area of knowledge that was not needed in the developing of the psycho-motor skills typical to metalworking. This might include the topic of the historical development of the lathe, which provided background knowledge, but which is not needed in the actual operation of a lathe. Two, the instrument also measured the area of knowledge that is needed in developing psycho-motor skills, such as the method of determining the optimal operating speed of a lathe. The retention of psycho-motor skills themselves, such as machining a pulley using a lathe, were to be measured using a separate instrument, which will be discussed later in section 3.3.3.

To obtain an accurate judgement as to which of the two categories of knowledge each item measured, a panel of three Metalwork instructors was used. Each taught senior Metalworking courses. One had thirty-one years teaching experience as well as being a journeyman machinist, one had twenty years teaching experience, and the third had five years teaching experience and was a journeyman machinist.

The researcher initially categorized the items, and then the panel reviewed the items separately and collectively. When consensus had been reached on an item it was considered categorized.

The 150 item test was composed of equal numbers of items measuring knowledge used in skill development and items measuring knowledge not used in skill development.

This collective test was split into three comparable subtests, and piloted in the two Metalwork 11 classes and one Metalwork 12 class, in March. Results of these subtests were analyzed statistically and ranked again according to the criteria indicated previously. From these categories a tentative final instrument of 64 questions was constructed, consisting of 32 questions specifically measuring knowledge not used in skill development, and 32 measuring knowledge that was used. In each of these two categories, 10 group mastery items were included.

3.3.2.5 Validity of the Instrument

Validity of the final 64 question test was determined in three ways. First, the panel of Metalwork teachers reviewed the items and the Metalwork 11 curriculum to judge to what extent the test actually measured the knowledge that it was intended to measure. Items judged to be non-valid were removed and replaced with ones judged to be valid, from the bank of 150 piloted and analyzed items. Each teacher then rated the final instrument on a rating scale of 1 to 5, with 1 being minimal validity and 5 being high validity. Each member of the panel rated the final instrument '5'.

Second, logical or sampling validity was ensured by developing a detailed table of specifications based on an outline of curriculum topics. Fifteen topics were included, with four types of knowledge for each. This table of specifications was updated upon analysis of the June test. Some changes had to be made from the planned categorization of each question, because of changes in the response rate. These changes were primarily in the group mastery/group non-mastery categories. The final table of specifications is illustrated in Figure 3.1.

Once the final piloting of these 150 items was complete, the choice of the 64 items to be used was again guided by the curriculum guide and table of specifications (Figure 3.1).

A substantial amount of effort went into assuring logical validity, since logical validity is "especially useful in the development of achievement tests."[4, p.96]

Third, concurrent validity was assessed upon use of the instrument. The total scores of the students' achievement in the knowledge aspect during the course, based on scores on short answer type tests, lab book assignment marks, as well as multiple-choice tests and quizzes, was correlated with the scores on the final retention test administered in

TOPIC	Non-Group mastery Not Used	Non-Group mastery Used	Group mastery Not Used	Group mastery Used	TOTAL PER TOPIC
Grinding & Abrasives	5		1		6
Calculations		2			2
Foundry & Forge			2	2	4
Cut-off Machines		1		2	3
Measurement		2		1	3
Hole Machining		3		1	4
Lathe	2	5	1	1	9
Milling Machine	1	1	2		4
Metallurgy	4				4
Pipe	3				3
Threads	1	2			3
Hand Tools	3	1			4
Arc Welding	1	2	3	1	7
Arc Welding Machines	3				3
Oxy-Acetylene	1	2		2	5
TOTAL PER TYPE	24	21	9	10	64

Figure 3.1: Table of specifications

June. The result of this test of validity was a Pearson Product Moment correlation of .707.

The validity of the knowledge test instrument was judged to be of a high standard, based on these three validity evaluations.

3.3.2.6 Reliability of the Instrument

To determine the reliability of the test, the data from the three subtests were combined, and then each of the questions that was to be deleted in the process of formation of the final instrument was deleted from the statistical analysis. Thus the initial analysis dealt only with the actual instrument that was used in the pre and post-testing.

Cronbach's alpha of this derived 60 question instrument was .802. This reliability measure was based on the pilot testing as described. The reliability of the instrument when used in the June test was .832, and was .817 when used in the September post-test. Reliability measures were calculated using Cronbach's Alpha (See Chapter 4 for more statistical information regarding the test results).

Because the test instrument was used in a retention study, test-retest reliability was also calculated. This measure of reliability was appropriate to this study because the test instrument was used in a test-retest method. The same instrument was administered in June and in September. Using a Pearson product-moment correlation, the coefficient was determined to be .934.

The development of this instrument involved many hours of study and organization of items and analyses. While the effort has resulted in an instrument that satisfies the demands of validity and reliability within a reasonable level, it is still limited to areas that can be measured with pencil and paper. In a Metalwork course this is a serious limitation.

To address this problem, a sample skill was also tested. Procedural skills are similar enough to verbal skills to be measurable with pencil and paper instruments. A skill was desired that was closer to the continuous psycho-motor skill that can only be measured by performance of some sort. This polarization between knowledge and skill was desired to clarify any difference that may exist in the retention patterns of these areas, as measurement of retention is the intended use of both the knowledge and the skill instruments. The following section on this paper deals with skill measurement.

3.3.3 Development of the Skill Instrument

This section will discuss the method that was used to develop the skill measuring instrument, and will provide a detailed description of the final instrument.

3.3.3.1 Choice of the Skill

Much of the work required in developing an instrument to measure a single continuous psycho-motor skill is spent on detailed analysis of the skill, and development of appropriate rating scales, as opposed to developing an objective instrument where much of the time is used in developing the instrument itself. Of the motor skills taught in Metalwork 11, some are procedural and some are continuous in nature. As previously stated, it is the continuous skill that is most distinct from the cognitive processes and knowledge that can be measured with multiple-choice items. Thus it was a continuous skill that was chosen for this study.

A second requirement of the skill was that it should be measurable by inspection of the product as opposed to inspection of the skill rehearsal itself, which could not be done because of time constraints in the classroom situation. Also, because of classroom considerations, and the unavailability of sufficient numbers of evaluators, it was impossible to have several evaluators observe the performance of the skill.

After consultation with the other Metalwork teachers on the evaluation panel it was decided that arc welding was the most suitable choice because it could be measured accurately through study of the actual weld after the rehearsal is complete, thus enabling scoring by several raters for each examinee. Further, arc welding is second only to the general category of lathework in terms of the importance and time given to the development of the skill in the Metalwork 11 course, and, as such, possessed high logical validity as a skill to be tested.

3.3.3.2 Description of the Skill

The arc welding skill chosen, building up a surface with weld metal, is termed 'padding'. Walker [102, p.49] identifies padding as a common operation in metal fabrication and repair, and further recommends the operation as "very important from the skill development standpoint" [102, p.49].

Arc welding skill consists of the correct manipulation of the welding rod to maintain correct arc length, rate of movement, angle of welding rod to metal, and also amperage setting and adjustment. Padding requires each of these four basic skills. Tuttle and Sear [98] describe padding as showing "whether or not the operator can manipulate machine setting, arc length, angle of electrode and speed of travel" (p.161).

3.3.3.3 Scoring Criteria of the Skill Instrument

To develop reliable scoring criteria the panel gathered 10 student-produced arc weld pads, chosen randomly from those made by Metalwork 11 students in the two previously mentioned secondary schools. These were inspected closely and compared to a photograph of welds of various quality.

For each characteristic, two photographs were presented for each possible score for that characteristic. For example, a score of 3 out of a possible 4 on bead width would have photographs of parts of two welding pads that illustrated this score. A total of 44 photographs were used. Each photograph was life size. A short paragraph described the weld pad segments that were shown, and explained why they received a given score for a given characteristic (see Appendix A).

The pre-test (June) pads were sprayed with a splash of red paint on the underside. This was not visible to the raters during the scoring, nor were the raters told if the painted pads were pre-test or retention test pads. The purpose was to allow separate recording of scores for painted pads (June test) and non-painted pads (September test).

The scoring criteria was outlined as follows:

Bead Width	/4
Bead Overlap	/4
Cross Sectional Shape (height 20% of width)	/4
Ripple Shape and Spacing	/4
Amount of Spatter (minimal)	/3
Crater Location and Filling (complete, even)	/3
Total	/22

Bead Width: Exact bead width is not the concern here, rather it is important that the bead be the same width throughout its length, as consistently as possible. Continuous width indicates correct manipulation of the welding arc. Although bead width is not the major concern, it should be between 8 mm and 11 mm for the purposes of this measuring instrument.

Scores for this characteristic:

1. A score of 1 is given where the width of some bead segments is over 100% greater than the width of other segments on the same pad. Pads may also be scored 1 out of 4 for this characteristic if bead width is not between 6 mm and 13 mm.

2. This score (2) is given where bead segments are over 50% but less than 100% greater than the width of other bead segments. Pads may also be scored 2 out of 4 if average bead width is not between 8 mm and 11 mm, but is within 1.5 mm of these boundaries.

3. Bead width must be quite consistent to be scored 3 out of 4, but irregularities may cause bead width of some segments to be over 25% but less than 50% greater than the width of other segments. Average width is between 8 mm and 11 mm.

4. These beads must have very consistent width, varying less than 25%, in order to score 4. Overall width must be between 8 mm and 11 mm.

Bead Overlap: Again, exact amount of overlap of beads is not as important as consistency, which indicates control of the welding rod manipulation. However, it is a concern if the overlap becomes minimal (less than 10% of bead width) or excessive (greater than 25% of bead width).

Scores for this characteristic:

1. A score of 1 may be given for various reasons. Beads may overlap very inconsistently, with some beads overlapping others from 75% to 100%, while in other places there is no overlap. This score may also be given if the overlap is consistent, but is greater than 75% or where there is no overlap at all.

2. This score (2) is given when there is generally some overlap, but it is inconsistent, ranging from 0% to 75% of bead width.

3. Pads having beads that overlap fairly consistently will score 3 if this overlap is greater than 0% but less than 50% of bead width.

4. Pads that score 4 for bead overlap have overlap that varies less than 25% and ranges from 10% to 30% of bead width.

Cross sectional shape: The height of the bead should be close to 25% of the width of the bead. Greater height indicates an incorrect setting of the arc welding machine (amperage too low). If the bead height too low, the evaluator can accurately conclude that the amperage setting was too high.

Scores for this characteristic:

1. A score of of 1 will be given to pads that have beads with a height to width ratio of greater than 75% or less than 5%.
2. A score of 2 is assigned to welds that have average height between 5% and 15% of width (too flat) or between 40% and 75% of width (too high).
3. Pads scoring 3 on this characteristic have beads that are quite close to a desirable ratio of height to width. The average height is between 30% and 40% of width or between 15% and 20% of width.
4. This score (4) is given when beads have consistent height which is between 20% and 30% of bead width.

Ripple Shape and Spacing: All welding beads have small ripples on the surface, caused by the freezing of the molten puddle as the arc proceeds along the metal. If the ripples are semi-circular the rater may conclude that the angle of the welding rod with respect to the pad was correct. If the ripples are not semi-circular in shape (if they are pointed), then the conclusion may be drawn that the welding rod was at too great an angle to produce a high quality weld.

Small, evenly spaced but distinct ripples indicate correct rate of travel. Ripples that are very close together and indistinct indicate a travel rate that is too slow. Ripples too far apart indicate that the travel rate is too fast, while inconsistent spacing indicates inconsistent speed.

Scores for this characteristic:

Scores here are based on regularity of the ripple spacing and shape. If some of the ripples on a pad are very large, and others very small, or if some are semi-circular while others are very flat or very pointed, then the score will be 1 out of 4. If the ripple patterns are very consistent, with the shape being almost exclusively semi-circular, then the score will be 4 out of 4. Varying degrees of these characteristics will result in scores of 2 or 3 out of 4. To determine these accurately, refer to Appendix A for photographs that show the scoring for this characteristic.

Amount of spatter: Spatter consists of the small droplets of steel that splash out of the arc and attach themselves to the weld metal. This is an undesirable by-product of the arc welding process, and should be kept to a minimum by controlling arc length (the distance from the rod the pad) and amperage (higher amperage produces more spatter). Therefore minimum spatter is desired.

Scores for this characteristic:

1. A score of 1 out of 3 is given where there is excess spatter, and more than 20 large (approximately 1.5 mm) droplets of metal can be counted.
2. When a pad shows between 7 and 20 droplets of spatter it then fits into the 2 out of 3 scoring category.
3. Pads scoring 3 out of 3 will have minimal spatter (less than 7 significant droplets on the pad).

Crater Location and Filling: Ideally, the termination of the weld bead is not performed at the edge of the metal, because this termination produces a 'crater' which tend to melt off the edge of the pad, and tends to be a weak spot in the weld bead. When located at the end of a weld bead, this weak spot may result in later cracking. To rectify this situation, the termination of the welding occurs somewhere other than at the edge of the pad, and the crater is filled with weld metal. The rater looks for a completely filled crater so that the height of the bead is retained at the crater area. Porosity in the crater is to be avoided.

Scores for this characteristic:

1. To score a 1 out of 3, a pad will have craters that are very concave, or are at the end of the bead as opposed to anywhere but the end, or have extreme porosity.
2. Pads with craters that are moderately concave, or are not aligned, or that have moderate porosity, will be scored 2 out of 3.
3. A score of 3 out of 3 will be given to pads that contain craters which are filled to a height that is equivalent to that of the beads, and have minimal or no porosity.

Each criterion, for each characteristic, is explained and illustrated further in Appendix A.

3.3.3.4 Piloting of the Skill Instrument

A piloting of the skill measuring instrument was conducted early in the school year, after the initial two months of practice trials in arc welding. This test was conducted in early November, seven months before the end-of-course testing in June. The same students were measured in the pilot as were measured in June and September of the following calendar year.

The purpose of analyzing the pilot testing was to ascertain validity of the welding skill instrument, and to determine if the instrument differentiated well between poor welders and more highly skilled welders.

The scores on the welding pilot were correlated with the scores achieved in the total psycho-motor component of the Metalwork 11 curriculum, after three terms. The Pearson product-moment correlation was .625, which indicated relatively high concurrent validity.

3.3.3.5 Validity of the Skill Instrument

Face validity was obtained in the initial discussions with the panel of Metalwork teachers, when it was agreed that arc weld padding was a sound method of measuring metalwork skill attainment.

Prior to making a final decision to use the padding skill as a sample of a psycho-motor skill, the validity of padding in terms of how well it measures a sample of the various skills used in metal fabrication was investigated. To do this the scores from the psycho-motor skill aspect of the curriculum were correlated with scores received on the arc welding instrument upon the June testing. The psycho-motor skill scores were those based on the grading of the two major projects that comprised the hands on component of the year's work. The factual knowledge that was measured with pencil and paper testing was not included in this correlation, because the welding pad was not intended to measure this aspect of Metalwork 11. The Pearson product-moment correlation coefficient was calculated to be .633.

3.3.3.6 Reliability of the Skill Instrument

To maximize inter-rater reliability, the panel of raters was trained in rating each criteria. A sample of weld pads was collected and each criteria will be discussed as it applied to each pad. The scoring procedure for the actual welding pads was conducted in September, once all the initial testing and retention testing was completed. All pads were be collected at this time, with the pre-test pads and the retention test pads intermingled. In this way the raters were be able to rate all pads consistently, not knowing which student produced which pad, and not knowing which pad was a retention pad or a pre-test pad.

Each criteria was evaluated separately. All pads were scored on the first criteria, then all pads scored on the second criteria, etc. This was done to maximize comparison between pads, and to maximize inter-rater reliability.

To ascertain inter-rater reliability three Pearson product-moment correlations were calculated, using the three possible paired combinations of the three raters. These values were .83, .86 and .91 and averaged to .87 to represent the inter-rater reliability.

Test-retest reliability was not an appropriate measure of reliability for the skill testing instrument, because of the fact that a large percentage of the students were found to have practiced their welding skills over the summer, while other students did no such practicing.

3.3.4 Conclusion

Both the multiple choice and the continuous motor skill instruments developed for this study were evaluated for face, logical, and concurrent validity. Accepted methods for measuring and ensuring reliability were employed. Careful and detailed piloting and item analysis was completed for over three hundred multiple-choice items, with the best items forming a sixty four item instrument. An experienced panel was assembled and consulted in the development and scoring of the skill testing instrument, and detailed criteria for scoring was developed. As a result of these efforts the researcher has confidence that the instruments could reliably and validly measure the retention of Metalwork 11 skill and knowledge.

3.4 Method of Analysis

A repeated measures design was employed to explore the retention patterns of the subjects of this study. As described in Sections 3.1 and 3.2, both the knowledge and the psycho-motor skill instruments were administered in June and again in September. The pretest and posttest scores became one of the factors that were considered.

In order to address the hypotheses as outlined in Chapter 1 (see Section 1.3, page 6), the knowledge instrument was divided into groups of items that measured:

- Group mastery knowledge;
- Group non-mastery knowledge;
- Knowledge used the the development of psycho-motor skills;
- Knowledge not used in the development of psycho-motor skills.

To facilitate thorough analysis of the retention effects of use of knowledge and the effects of group mastery learning, these variables were combined in these ways:

- All items (Al);
- All Group mastery items (M);
- All Group non-mastery items (NM);
- All Used Knowledge items (U);
- All Not Used Knowledge items (NU);
- Not Used, Group non-mastery items (NUNM);
- Used, Group non-mastery items (UNM);

- Not Used, Group mastery items (NUM);
- Used, Group mastery items (UM);
- Continuous Psycho-Motor skill (PAD).

The psycho-motor skill measuring instrument provided the continuous motor skill variable that was added to this list.

Subjects were grouped according to four factors:

- School Major (Major):
  1. Industrial Education (IE),
  2. Not Clear (NC),
  3. Academic (Acad);
- Metalwork Course Marks (MWMark):
  1. Low (< 58) (Lo),
  2. Middle ($58 - 64$) (Mid),
  3. High (> 64) (Hi);
- Marks in Core Courses taken in 1987/88 (MarkC):
  1. Low ($\leq GPA = 2.0$) (Lo),
  2. High ($> GPA = 2.0$) (Hi);
- Summer Metalwork Experience (Summer):
  1. None (No),
  2. 1 to 4 hours (1-4),

3. > 4 hours (> 4).

These groupings were formed in order to provide information that could lead to tentative explanations of the retention patterns found upon analysis of the knowledge and skill variables.

To test the hypotheses presented in Section 1.3, multivariate analysis of variance was used. Although analysis of variance was considered, it soon became clear that the number of ANOVAs needed, to determine main effects as well as possible interactions, was very large. This would have produced a very high possibility of a Type 1 error. To reduce this possibility, as well as to increase statistical power in order to reduce the possibility of a Type 2 error, MANOVA's were used.

The first series of MANOVAs consisted of three runs. The first run was a MANOVA on the variables without any consideration of the four factors. The second run was done as a four factor analysis, splitting the students up on the four factors. The third run used the subject groupings by major and summer experience, but using the measures of achievement (core course marks and Metalwork marks) as covariates.

These MANOVAs showed that groupings by major and summer experience resulted in very small groups, so the second and third run were repeated but with these two factors as dichotomies. Major was split into two groups; Industrial Education major and non-Industrial Education major. Summer experience was split into a yes/no dichotomy. These two series of MANOVA analyses provided the basis for the results of Chapter 4 and the conclusions of Chapter 5.

Chapter 4

Results

4.1 Introduction

This chapter deals with the results of the analysis as outlined in Chapter 3. The results of each series of MANOVAs will be presented and discussed, along with their implications for the hypotheses presented in Chapter 1.

4.1.1 Overview of Results

Several important results were apparent. First, knowledge that was used in the development of psycho-motor skills was retained to a significantly higher level than was knowledge that was not used in psycho-motor skill development. Using the knowledge reduced forgetting of that knowledge.

Second, knowledge that was learned to a high original level of achievement was forgotten to a significantly greater extent than was knowledge that was learned to lesser levels of achievement. However, although more was forgotten in the group mastery level area, more was retained as well.

Third, psycho-motor skills were retained at a significantly greater level than than was knowledge that was not used in the development of these psycho-motor skills, but was not retained at a significantly greater level than knowledge that *was* used in psycho-motor skill development.

Fourth, when knowledge that was used in skill development was learned to group mastery level, no significant forgetting was found.

Overall, when all verbal-based learning was combined, significant forgetting was found. This was not the case when psycho-motor skill (activity-based) learning was considered.

4.2 Analyses Which Did Not Consider Effects of Grouping Factors

This series of MANOVA runs analyzed the means of the variables without consideration for the grouping factors (see Section 3.4, page 85 for lists of variables and factors). This section will deal with areas of learning that experienced statistically significant change when analyzed in this way. Other analyses that shed light on these results will also be discussed in this section. Results will be related to the hypotheses that were tested in this study.

4.2.1 Restatement of Hypotheses

For the benefit of the reader, the hypotheses that were presented in Chapter 1 will be restated here.

1. Continuous psycho-motor skills (PM) will not be retained at a significantly higher percentage than the knowledge used (UK) in acquiring skills.

    - H_O: $X_{diff_{PM}} = X_{diff_{UK}}$
    - H_A: $X_{diff_{PM}} < X_{diff_{UK}}$

    (Difference (Diff) refers to the difference in scores between the June and September administration of the measuring instruments, which is a measurement of the forgetting that took place).

2. Knowledge used (UK) in acquiring skills will not be retained at a significantly higher percentage than knowledge not used (NUK) in skill acquisition.

   - H_O: $X_{diff_{UK}} = X_{diff_{NUK}}$
   - H_A: $X_{diff_{UK}} < X_{diff_{NUK}}$

3. Group mastery learning (M) will not produce a significantly lower retention level than is found in the group non-mastery (NM) knowledge areas.

   - H_O: $X_{diff_M} = X_{diff_{NM}}$
   - H_A: $X_{diff_M} > X_{diff_{NM}}$

4. Students enrolled in two or more Industrial Education electives (IE) will not retain a significantly different amount of knowledge not used in psycho-motor skill development (NUK) than will students enrolled in two or more academic electives (AE).

   - H_O: $X_{diff_{IE_{NUK}}} = X_{diff_{AE_{NUK}}}$
   - H_A: $X_{diff_{IE_{NUK}}} \neq X_{diff_{AE_{NUK}}}$

5. Students enrolled in two or more Industrial Education electives (IE) will not retain a significantly different amount of psycho-motor skills (PM) than will students enrolled in two or more academic electives (AE).

   - H_O: $X_{diff_{IE_{PM}}} = X_{diff_{AE_{PM}}}$
   - H_A: $X_{diff_{IE_{PM}}} \neq X_{diff_{AE_{PM}}}$

6. Students with a grade point average which falls in the top one third of the class (HGPA) in the core areas will not have a significantly different rate of retention

in all measured areas of Metalwork 11 curriculum than do students with a GPA in the core subjects which falls in the bottom one third of the class (LGPA). See definitions on page 8 for explanation of GPA system.

- H_O: $X_{diff_{HGPA}} = X_{diff_{LGPA}}$
- H_A: $X_{diff_{HGPA}} \neq X_{diff_{LGPA}}$

7. Students with high metalwork marks (HMM) in the Metalwork 11 course (top 25% of year average marks) will not retain a significantly different amount of all measured Metalwork 11 curriculum areas than students with low marks (LMM) in Metalwork 11 (bottom 25% of students).

   - H_O: $X_{diff_{HMM}} = X_{diff_{LMM}}$
   - H_A: $X_{diff_{HMM}} \neq X_{diff_{LMM}}$

8. Students who practice a psycho-motor skill (PR) during the retention interval will not retain that skill at a higher level than students who do not practice that skill (NPR) during the retention interval.

   - H_O: $X_{diff_{PR}} = X_{diff_{NPR}}$
   - H_A: $X_{diff_{PR}} < X_{diff_{NPR}}$

4.2.2 All Items

Table 4.1: MANOVA F-Table for All Items

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	101.39	21	4.83		
ALL ITEMS	79.11	1	79.11	16.39	.001

Table 4.2: Means for All Items

TEST	MEAN	STD. DEV.
June	38.46	8.63
Sept	35.77	8.37
Difference	-2.71	

The results shown in Table 4.1 show that there was a significant change in score on the multiple choice instrument between the June and September administration. The data presented in Table 4.2 show that this difference was a decrement, representing loss from a mean of 38.46 in June to a mean of 35.77 in September. This loss represents forgetting of slightly less than 7%, of the original score, over a period of three months.

The literature indicates that very often there is an overall loss of the knowledge area of secondary school learning that is substantially higher than that found here, often 10% to 50% [23,35,88,91]. Further analysis provided indications of the specific sources of the statistically significant loss, and areas of loss that have high practical significance, and provided foundations for possible explanations.

When the analysis considered the effects of grouping factors, significance of the F ratio was reduced to .02 (see Table 4.3) due to the smaller numbers of students in each group. Using the factors of students' marks in Metalwork 11 and their GPA in core courses as two covariates, significance of the F ratio was further reduced to .06 (see Table 4.4). Additional removal of the effects of students' major and their summer skill practice resulted in a slight further loss of significance of the F ratio to .10 (see Table 4.5). These grouping factors do account for some of the variation, but do not entirely explain the retention loss found between the June and September administration of the multiple choice instrument, when all measured types of learning are considered in combination.

Table 4.3: F-Table for All Items, Considering Groups

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	26.62	8	3.33		
ALL ITEMS	27.04	1	27.04	8.12	.02

Table 4.4: F-Table for All Items. Covariates: GPA in Core Courses, and Mark in Metalwork 11

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	51.20	14	3.66		
REGRESSION	4.39	1	4.39	1.20	.29
ALL ITEMS	15.85	1	15.85	4.33	.06

4.2.3 Knowledge not used in Skill Development

This area of learning involves content that is not necessary in the development of the psycho-motor skills contained in the Metalwork 11 curriculum.

Tables 4.6 and 4.7 show that when only 'not used knowledge' item means were analyzed, the loss was somewhat greater (9.4% of original score) than the loss for all items combined. In comparison, when 'used knowledge' item means were analyzed the results indicated no statistically significant change. This indicates that knowledge which is not used in the development of skills is retained significantly more poorly than if this knowledge is used in the development of skills.

These tests of statistical significance relate directly to Hypothesis 2. The null version

Table 4.5: F-Table for All Items. Covariates: GPA in Core Courses, Mark in Metalwork 11, Summer Skill Practice, and Major

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	92.83	19	4.89		
REGRESSION	8.56	2	4.28	.88	.43
ALL ITEMS	14.56	1	14.56	2.98	.10

Table 4.6: MANOVA F-Table for Not Used Knowledge

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	97.30	21	4.63		
NOT USED KNOWLEDGE	38.20	1	38.20	8.25	.01

Table 4.7: Means for All Not Used Knowledge Items

TEST	MEAN	STD. DEV.
June	19.82	5.28
Sept	17.96	5.10
Difference	-1.86	

of this hypothesis states that: knowledge used (UK) in acquiring skills will not be retained at a significantly higher percentage than knowledge not used (NUK) in skill acquisition.

- H_O: $X_{diff_{UK}} = X_{diff_{NUK}}$
- H_A: $X_{diff_{UK}} < X_{diff_{NUK}}$

(see Section 1.3, page 6 for the complete statement of hypotheses)

The results shown in Tables 4.6 and 4.7 provide evidence that required the rejection of the null hypothesis and acceptance of the alternate hypothesis. This alternate hypothesis states that significantly less difference will be found between June and September means for 'used knowledge' than will be found for 'not used knowledge' over the same interval.

Although there is limited literature in the area of retention effects of use of knowledge, and it is not in the area of Industrial Education, the results of those studies available are generally in agreement with the results of the present study (see Section 2.3.3.3, page 56 for a review of the applicable research).

When the analysis considered the effects of grouping factors, statistical significance was lost (Significance of the F ratio was .25) due to low numbers of students in each group, with retention loss spread out relatively evenly among those groups (see table 4.10). However, when the effects of the factors Metalwork 11 mark, and GPA in core courses, were removed by making them covariates, the remaining variation neared statistical significance, as shown in Table 4.8.

Table 4.8: F-Table for Not Used Knowledge, With Metalwork 11 Mark and GPA in Core Courses as Covariates

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	53.19	14	3.80		
REGRESSION	6.72	1	6.72	1.77	.21
NOT USED KNOWLEDGE	15.66	1	15.66	4.12	.06

A further gain in power, produced by an analysis that added two more covariates (students' major and summer skill practice) provided the statistically significant result seen in Tables 4.9 and 4.10. Retention loss, in knowledge that is not used in skill development, cannot be accounted for by the four factors that were used in this study.

Table 4.9: F-Table for Not Used Knowledge, With Metalwork 11 Mark, GPA in Core Courses, Major and Summer Skill Practice as Covariates

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	84.35	19	4.44		
REGRESSION	12.94	2	6.47	1.46	.26
NOT USED KNOWLEDGE	21.50	1	21.50	4.84	.04

4.2.4 Group mastery Level Knowledge

Group mastery level learning, as defined for this study, consists of knowledge measured by items that attained a mean correct response rate of higher than 70% at the

Table 4.10: Means for All Not Used Knowledge Items by Factor

	Factor	JUNE		SEPT		
FACTOR	Level	Mean	N	Mean	N	Diff
Major	I.E.	18.56	9	15.56	9	-3.00
	Not Clear	19.80	10	19.20	10	-0.60
	Academic	23.67	3	20.27	3	-3.40
Summer	None	21.90	10	19.50	10	-2.40
	1 - 4 hr.	19.00	4	18.50	4	-0.50
	> 4 hr.	17.63	8	15.75	8	-1.88
GPA	Low	18.47	15	17.20	15	-1.27
	High	22.71	7	19.57	7	-3.14
Mark	Low	14.20	5	13.40	5	-0.80
	Middle	20.46	13	18.00	13	-2.46
	High	24.75	4	23.50	4	-1.25

June administration of the multiple choice instrument (see Figure 3.1, page 74 for the table of specifications listing group mastery item topics and numbers).

The research regarding retention of mastery level learning, as summarized in Section 2.3.3.1, provides evidence that those students who obtain the highest level of initial learning also lose the most, although their relative standings remain little changed [10,18,20]. These findings are echoed in the present study, confirming their generalizability to the knowledge area of the Metalwork 11 curriculum, and strongly suggesting generalizability to the Industrial Education area as a whole.

Table 4.11: MANOVA F-Table for Group mastery Level Knowledge

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	46.18	21	2.20		
ALL GROUP MASTERY ITEMS	32.82	1	32.82	14.92	.001

Tables 4.11 and 4.12 show that group mastery level knowledge suffered a mean decrement of 10.6% of original learning, from June to September. This loss was statistically

Table 4.12: Means for Group mastery Level Knowledge Items

TEST	MEAN	STD. DEV.
June	16.23	2.84
Sept	14.50	2.81
Difference	-1.73	

significant, while there was no significant change in means of the 'group non-mastery' knowledge area when all group non-mastery learning was combined.

However, several interactions involving used, group non-mastery level learning, were statistically significant, as shown by Tables 4.13, 4.14, 4.15, 4.16, 4.24, 4.25, 4.26, and 4.27. These significant interactions were:

- 'Used, group non-mastery' knowledge by 'Major' by 'Summer skill practice';
- 'Used, group non-mastery' knowledge by 'Major' by 'Course Mark';
- 'Used, group non-mastery' knowledge by 'Major' by 'GPA (core courses)';
- 'Used, group non-mastery' knowledge by 'GPA (core courses)'.

Table 4.13: F-Table for Used Group non-mastery by Major by GPA (Core) Interaction

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	6.50	8	.81		
Used Group Non-mastery x Major x GPA	18.38	1	18.38	22.62	.001

As shown in Tables 4.13 and 4.14, interactions between groups by Major and GPA for 'used, group non-mastery' learning show changes in score from a gain of 13% to a loss of 25% of original score. Table 4.14 illustrates that the predominant pattern of retention was directly related to initial score, and indirectly related to group interactions.

Table 4.14: Means for Used Group Non-mastery by Major by GPA (Core) Interaction

Major	GPA	JUNE Mean	N	SEPT Mean	N	Diff
I.E.	Low	8.50	6	8.17	6	-0.33
	High	10.00	3	11.33	3	+1.33
Not Clear	Low	10.38	8	11.00	8	+0.62
	High	12.00	2	9.00	2	-3.00
Academic	Low	16.00	1	13.00	1	-3.00
	High	12.50	2	12.00	2	-0.50

The three highest means (12.00 for High GPA + Not Clear Major, 16.00 for Low GPA + Academic Major, and 12.50 for High GPA + Academic Major) show relatively large losses (averaging 15.9%). The three lowest means (8.50 for Low GPA + I.E. Major, 10.00 for High GPA + I.E. Major, and 10.38 for Low GPA + Not Clear Major) show an average gain of 5.1%.

It seems probable that the findings presented earlier in this section regarding the retention effects of initial level of learning also explain the effects seen here. The interaction between students' major and GPA may have been statistically significant because students with an Industrial Education major tended to initially score lower in knowledge areas than did students with an Academic major. The group interactions between major and GPA served to maximize the difference in achievement levels. Thus the pattern of retention can possibly be explained by reference to initial level of learning.

This explanation is also a reasonable alternative when looking at the interaction between 'Used Group non-mastery' knowledge by 'Major' by 'Summer Experience'. Table 4.16 shows that higher initial scores tended to result in greater loss, while lower scores produce little loss or even gain.

The results shown in Tables 4.25 and 4.24 also indicate that differences in initial level of learning are clearly related to the interaction of students' major by their course

Table 4.15: F-Table for Used Group non-mastery by Major by Summer Interaction

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	6.50	8	.81		
Used Group non-mastery by Major by Summer	15.78	2	7.89	9.71	.01

Table 4.16: Means for Used Group non-mastery by Major by Summer Interaction

Major	Summer Practice	JUNE Mean	JUNE N	SEPT Mean	SEPT N	Diff
I.E.	None	9.00	3	9.67	3	+0.67
	1 - 4 hr.	13.50	2	10.50	2	-3.00
	> 4 hr.	6.75	4	8.25	4	+1.50
Not Clear	None	11.50	4	12.25	4	+0.75
	1 - 4 hr.	9.00	2	9.00	2	0
	> 4 hr.	10.75	4	9.75	4	-1.00
Academic	None	13.67	3	13.00	3	-0.67
	1 - 4 hr.	-	0	-	0	-
	> 4 hr.	-	0	-	0	-

mark. These initial differences result in differences in retention rates. Again, the lowest three scores are found in the IE and Not Clear majors. These interactions show either no change or slight gain in learning (gains averaged 2.3%). The upper three scores, which are found in the interaction between 'Not Clear' major by High course mark and the interactions involving academic majors, show losses from 4% to 18.8%.

Another explanation is possible when looking at the interactions involving 'used, group non-mastery' knowledge. There is at least one outlier in this area of learning. This outlying score represents an academic major, with no summer skill practice, a low course mark and a low GPA in core courses. However, although the course mark and GPA are low, in the area of 'used, group non-mastery' knowledge the initial score (76%) was the highest obtained initial score (tied with one other student).

When tested again in September this student's mark experienced an 18.8% loss, compared with a group mean of 1.3% loss. In groupings involving 'used, group non-mastery' knowledge the small sample size became important. In the Major by Course Mark by 'Used, group non-mastery' Knowledge interaction, this student was the only member in a group. In the Major by Summer by 'Used, group non-mastery' Knowledge interaction, this student was in a group with only two others.

This case was one that was clearly seen because of the fact that in one interaction this student formed a group of one, showing the outlying position. It is possible and even probable that in interactions that often had group numbers as small as 1, 2, or 3, there were other cases of one outlying score having a large effect on the group score.

To test the possibility that very small group sizes and possible outliers were causing the statistical significance of these interactions, a separate series of MANOVAs were run, but with these changes made by compressing groups.

Summer skill experience was compressed from the initial three groups (0, 1 to 4 hours, and greater than 4 hours) to two groups (0, and 1 or more hours). Students' major was compressed from I.E., Not Clear, and Academic majors, to I.E. and non-I.E. majors. These two compressions changed group sizes from a mean of 2.44 to a mean of 5.50 students per group (see Tables 4.17 and 4.18).

This analysis showed no statistical significance for interactions involving 'used, group non-mastery' knowledge by GPA (see Tables 4.19 and 4.27), 'used, group non-mastery' knowledge by Major by Summer skill experience (see Tables 4.20 and 4.21), and 'used, group non-mastery' knowledge by Major by Course Mark (see Tables 4.22 and 4.23).

There was a significant change that occurred in these interactions when the group sizes were increased by compressing as previously described. This indicates that either the very small groups were being significantly influenced by outlying scores, or that the statistical significance was an artifact of the interactions, which tended to separate

Table 4.17: Uncompressed Group Sizes for Used Group non-mastery by Major by Summer Experience Interaction

MAJOR	Summer Practice	Uncompressed Group Sizes
I.E.	None	3
	1 - 4 hr.	2
	> 4 hr.	4
Not Clear	None	4
	1 - 4 hr.	2
	> 4 hr.	4
Academic	None	3
	1 - 4 hr.	0
	> 4 hr.	0

Table 4.18: Compressed Group Sizes for Used Group non-mastery by Major by Summer Experience Interaction

MAJOR	Summer Practice	Compressed Group Sizes
I.E.	None	3
	$\geq$ 1 hr.	6
Non-I.E.	None	7
	$\geq$ 1 hr.	6

groups on the basis of achievement as well as on the intended basis.

In the first possibility, compressing groups would keep the same data, but in providing larger groups would in effect be reducing the amount of influence any one score could have on the interaction, thus possibly reducing the statistical significance of that interaction. (It may also increase the statistical significance of the interaction, if the effect of the outlying score was to reduce significance when an interaction was initially analyzed). However, in the present situation the compressed grouping acted to reduce significance.

In the second possibility, compressed grouping would be reducing the unintended effect of the interaction to differentiate groups on the basis of initial achievement level.

Further testing and research would be required to see which, if either, or both, of these possibilities were the cause of the significant interactions when analyses were performed on the uncompressed groupings.

Table 4.19: F-Table for Used Group non-mastery by GPA in Core Courses (With Major and Summer Skill Experience as Dichotomies)

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	27.90	11	2.54		
Used Group non-mastery by GPA	.04	1	.04	.02	.90

Table 4.20: F-Table for Used Group non-mastery by Major by Summer Skill Experience (With Major and Summer Skill Experience as Dichotomies)

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	27.90	11	2.54		
Used Group non-mastery x Major x Summer	.38	1	.38	.15	.71

Table 4.21: Means for Used Group non-mastery by Major by Summer Interaction (With Major and Summer Skill Experience as Dichotomies)

	Summer	JUNE		SEPT		
Major	Practice	Mean	N	Mean	N	Diff
I.E.	< 1 hr.	9.00	3	9.67	3	+0.67
	≥ 1 hr.	9.00	6	9.00	6	0
Not I.E.	< 1 hr.	12.43	7	12.29	7	-0.14
	≥ 1 hr.	10.17	6	9.50	6	-0.67

These findings relate to hypothesis 3, which in null form states that group mastery learning (M) will not produce a significantly lower retention level than is found in the group non-mastery (NM) knowledge areas.

Table 4.22: F-Table for Used Group non-mastery by Major by Course Mark (With Major and Summer Skill Experience as Dichotomies)

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	27.90	11	2.54		
Used Group non-mastery x Major x Mark	8.24	1	8.24	3.25	.10

Table 4.23: Means for Used Group non-mastery by Major by Mark Interaction (With Major and Summer Skill Experience as Dichotomies)

Major	Course Mark	JUNE Mean	JUNE N	SEPT Mean	SEPT N	Diff.
I.E.	Low	7.75	4	7.75	4	0
	Middle	10.00	5	10.38	5	+0.38
	High	-	0	-	0	-
Not I.E.	Low	16.00	1	13.00	1	-3.00
	Middle	10.00	8	10.13	8	+0.13
	High	13.00	4	12.25	4	-0.75

- H_O: $X_{diff_M} = X_{diff_{NM}}$
- H_A: $X_{diff_M} > X_{diff_{NM}}$

The results shown in Tables 4.11 and 4.12 necessitated the conditional rejection of the null hypothesis, and conditional acceptance of the alternative hypothesis which states that there will be a greater loss of group mastery knowledge than there will be of group non-mastery knowledge, significant at the .05 level of confidence.

The null hypothesis is rejected, with the exception of one specific interaction, which

Table 4.24: F-Table for Used Group non-mastery by Major by Course Mark Interaction

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	6.50	8	.81		
Used Group non-mastery by Major by Mark	13.84	1	13.84	17.04	.003

Table 4.25: Means for Used Group non-mastery by Major by Course Mark Interaction

Major	Course Mark	JUNE Mean	JUNE N	SEPT Mean	SEPT N	Diff.
I.E.	Low	7.75	4	7.75	4	0
	Middle	10.00	5	10.38	5	+0.38
	High	-	0	-	0	-
Not Clear	Low	-	0	-	0	-
	Middle	10.00	8	10.13	8	+0.13
	High	13.50	2	12.50	2	-1.00
Academic	Low	16.00	1	13.00	1	-3.00
	Middle	-	0	-	0	-
	High	12.50	2	12.00	2	-0.50

Table 4.26: F-Table for Used Group non-mastery by GPA (Core) Interaction

Source of Variation	SS	DF	MS	F	Sig of F
Used Group non-mastery by GPA (Core)	10.08	1	10.08	12.41	.01

persisted in analysis that used compressed groupings as well as in analysis that used uncompressed groupings, namely 'Used' knowledge by 'Major' by 'GPA' (core courses).

For this interaction the null hypothesis is accepted, because there was no statistically significant difference in the retention between group mastery and group non-mastery learning in this area.

Table 4.27: Means for Used Group non-mastery by GPA (Core) Interaction

GPA	JUNE Mean	JUNE N	SEPT Mean	SEPT N	Diff.
Low	10.00	15	10.00	15	0
High	11.29	7	10.86	7	-0.43

4.2.5 Group mastery Learning Not Used in Skill Development

This section deals with learning that was not used in the development of skills, and was learned to group mastery level.

Table 4.28: MANOVA F-Table for Not Used Group mastery Level Knowledge

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	7.91	21	.38		
ALL ITEMS	9.09	1	9.09	24.14	.00

Table 4.29: Means for Not Used Group mastery Level Knowledge

TEST	MEAN	STD. DEV.
June	7.68	1.13
Sept	6.77	1.45
Difference	0.91	

When only the 'not used knowledge' aspect of group mastery learning was considered, Tables 4.28 and 4.29 display a rate of loss that was statistically as well as practically significant, with decrement being 11.8% of original learning level.

There was no significant loss in the 'used knowledge' aspect of group mastery learning, nor was there significant loss in the 'not used', 'not group mastery' learning. Apparently the use of knowledge in the development of psycho-motor skill was enough to allow retention of that knowledge, even when it was learned to an initially high level. Similarly, if knowledge was not used, but was not learned to a group mastery level, the learning did not suffer significant loss. However, in this case initial learning was not high, so retention in absolute terms was not as great as it was in group mastery learning of used knowledge.

To aid in an explanation of these results, analyses using general achievement measures (GPA in core courses, and Metalwork 11 course mark) as covariates were completed, as were analyses that used students' major and summer skill practice as additional covariates. The results of these MANOVAs indicated that these grouping factors accounted for the difference, between June and September, of scores in 'not used' group mastery learning (see Tables 4.30 and 4.31). Also, as shown in Table 4.32, the difference was approximately evenly divided among these four factors.

Table 4.30: F-Table for Not Used, Group mastery Level Knowledge, With Metalwork 11 Mark and GPA in Core Courses as Covariates

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	4.51	14	.32		
REGRESSION	1.07	1	1.07	3.33	.09
NOT USED GROUP MASTERY	.11	1	.11	.33	.58

Table 4.31: F-Table for Not Used Group mastery Level Knowledge, With Metalwork 11 Mark, GPA in Core Courses, Major and Summer Skill Practice as Covariates

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	7.78	19	.41		
REGRESSION	.13	2	.06	.16	.86
NOT USED GROUP MASTERY	.05	1	.05	.12	.73

4.2.6 Results of Analysis of Other Variables

Several other variables were analyzed, with no statistically significant differences found. These variables fall into this 'non-significant' category:

- Continuous Psycho-Motor skill;
- All Used Knowledge items;

Table 4.32: Means for Not Used, Group mastery Level Knowledge Items by Factor

FACTOR	Factor Level	JUNE Mean	JUNE N	SEPT Mean	SEPT N	Diff.
Major	I.E.	7.56	9	6.45	9	-1.11
	Not Clear	7.70	10	7.00	10	-0.70
	Academic	8.00	3	7.00	3	-1.00
Summer	None	7.90	10	7.00	10	-0.90
	1 - 4 hr.	7.75	4	6.75	4	-1.00
	> 4 hr.	7.38	8	6.50	8	-0.88
GPA	Low	7.53	15	6.53	15	-1.00
	High	8.00	7	7.33	7	-0.67
Mark	Low	6.80	5	5.80	5	-1.00
	Middle	7.85	13	7.00	13	-0.85
	High	8.25	4	7.25	4	-1.00

- All Group non-mastery items;
- Not Used, Group non-mastery items;
- Used, Group mastery items.

(See Section 3.4 for a complete list of variables that were tested).

Of immediate interest to this section is the applicability of the results of the tests applied to the continuous psycho-motor skill and the 'used knowledge' areas of learning. Hypothesis 1 states that continuous psycho-motor skills (PM) will not be retained at a significantly higher percentage than the knowledge used (UK) in acquiring skills.

- H_O: $X_{diff_{PM}} = X_{diff_{UK}}$
- H_A: $X_{diff_{PM}} < X_{diff_{UK}}$

There was no statistically significant loss in either the area of continuous psycho-motor skill learning or the area of knowledge used in the development of psycho-motor skills. It therefore followed that the null hypothesis was accepted, and the alternate hypothesis was rejected.

4.3 Analyses Which Considered Effects of Grouping Factors

These analyses consisted of MANOVA runs that took into account variations based on grouping factors. These were done as four factor analyses, splitting the students up on four factors:

- Major:
    1. Industrial Education,
    2. No Clear Major,
    3. Academic;
- Summer Psycho-motor Skill Experience:
    1. None,
    2. < 4 Hours,
    3. ≥ 4 Hours;
- Mark in Metalwork 11:
    1. Low ($< 58\%$),
    2. Middle (58% to 64%),
    3. High ($> 64\%$);
- Grade Point Average in Core Courses
    1. Low (≤ 2.0),
    2. High (> 2.0).

4.3.1 Areas of No Significant Interactions

There were no statistically significant interactions among groups for these areas of learning:

- All knowledge areas combined;
- All knowledge areas not used in skill development;
- All knowledge areas not learned to group mastery level;
- All knowledge areas that were learned to group mastery level;
- Knowledge not used in skill development, and not learned to group mastery level;
- Knowledge not used in skill development, but learned to group mastery level;
- Knowledge used in skill development, and learned to group mastery level;
- Continuous psycho-motor skill (arc welding).

The lack of significant interactions among groups for these areas of learning had implications for several hypotheses made earlier in Section 1.3. This section will deal with each interaction and the relevant hypotheses (see page 6 for a complete list of hypotheses).

4.3.1.1 Hypothesis 4

The fourth hypothesis, as presented in Section 1.3, states that students enrolled in two or more Industrial Education electives (IE) will not retain a significantly different amount of knowledge not used in psycho-motor skill development (NUK) than will students enrolled in two or more academic electives (AE).

- H_O: $X_{diff_{IE_{NUK}}} = X_{diff_{AE_{NUK}}}$
- H_A: $X_{diff_{IE_{NUK}}} \neq X_{diff_{AE_{NUK}}}$

Because there was no statistically significant interaction between students' major (Academic or Industrial Education) and 'not used' knowledge, the null hypothesis was accepted and the alternative hypothesis was rejected. This study found that students' concentration of study did not result in a different pattern of retention of knowledge that was not used in psycho-motor skill.

4.3.1.2 Hypothesis 5

Hypothesis 5, as a null hypothesis, states that students enrolled in two or more Industrial Education electives (IE) will not retain a significantly different amount of psycho-motor skills (PM) than will students enrolled in two or more academic electives (AE).

- H_O: $X_{diff_{IE_{PM}}} = X_{diff_{AE_{PM}}}$
- H_A: $X_{diff_{IE_{PM}}} \neq X_{diff_{AE_{PM}}}$

Statistical analysis showed that there was no significant interaction between students' major (IE or AE) and retention of psycho-motor skill. For this reason the null hypothesis was accepted and the alternative hypothesis was rejected. Whether the students enrolled in primarily Industrial Education or primarily non-Industrial Education electives was not a significant predictor of retention patterns of psycho-motor skills.

4.3.2 Core Courses Grade Point Average

Two measures of achievement were used in this study. One was the student's year's mark in Metalwork 11, which was a measure of the student's achievement in the Metalworking area. The other was the student's grade point average in the core courses taken during the year that he was enrolled in Metalwork 11. This formed a measure of the student's achievement in academic courses (for definitions of the grade point average system, and list of core courses, see Section 1.4, beginning on page 8).

These two measures were analyzed as factors, together with students' summer metalworking experience and major (see Section 4.3, page 108 for a more complete description of this analysis). The results of these analyses are relevant to hypotheses 6 and 7 as found in Section 1.3.

Statistical analysis resulted in two statistically significant interactions involving students' GPA in core courses. This section will detail these results and comment on their relevancy to Hypothesis 6.

Hypothesis 6 states that Students with a grade point average which falls in the top one third of the class (HGPA) in the core areas will not have a significantly different rate of retention in all measured areas of the Metalwork 11 curriculum than do students with a GPA in the core subjects which falls in the bottom one third of the class (LGPA).

- H_O: $X_{diff_{HGPA}} = X_{diff_{LGPA}}$
- H_A: $X_{diff_{HGPA}} \neq X_{diff_{LGPA}}$

Tables 4.26 and 4.27 show that knowledge that was used in skill learning, but was not learned to group mastery level, had statistically significant loss from June to September for students with high grade point averages in core courses. Students who fell into the low grade point average group did not experience any change in retention of 'used group non-mastery' knowledge.

While this difference between groups was statistically significant it is doubtful if there is any practical significance. The loss suffered by the high GPA group was less than 4% of original learning.

Grade point average in core courses interacted significantly with students' majors for two types of knowledge; one, knowledge used in skill development but not learned to group mastery level, and two, knowledge that was used in skill development, group mastery and group non-mastery levels combined.

Table 4.33: F-Table for All Used Knowledge by Major by GPA (Core) Interaction

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	19.71	8	2.46		
All Used by Major by GPA (Core)	16.67	1	16.67	6.77	.03

Table 4.34: Means for All Used Knowledge by Major by GPA (Core) Interaction

		JUNE		SEPT		
Major	GPA	Mean	N	Mean	N	Diff.
I.E.	Low	15.00	6	15.00	6	0
	High	19.33	3	19.67	3	+0.33
Not Clear	Low	19.00	8	18.50	8	-0.50
	High	21.50	2	16.50	2	-5.00
Academic	Low	24.00	1	21.00	1	-3.00
	High	21.50	2	20.50	2	-1.00

When the results seen in Tables 4.33 and 4.34 are viewed in the light of initial level of learning it appears that initial learning level may well account for the differences among groups. Separating out the highest three means (15.00 for Low GPA + I.E. Major, 19.33 for High GPA + I.E. Major, and 19.00 for Low GPA + Not Clear Major) the average change in score in 'used, group non-mastery' learning from June to September was a gain of 1.5%. The average change of the highest three means (21.50 for High GPA + Not Clear Major, 24.00 for Low GPA + Academic Major, and 21.50 for High GPA + Academic Major) was a loss of 13.5%. The smallest loss of the upper three means (4.7% of original score) was larger than the largest loss of the lower three means (2.6%).

Again, this result shows up in the Major by GPA (core courses) interactions because this interaction tends to maximize the difference in achievement, with Industrial Education majors receiving lower marks than Academic majors in the knowledge area of Metalwork 11.

Additional support is added to this explanation by the fact that overall, 'used, group non-mastery' knowledge showed statistically significant loss from June to September (see tables 4.35 and 4.36), when analyzed using a four factor MANOVA (see Section 4.3 for description of this MANOVA). However, when analyzed with 'Metalwork 11 course mark' and 'GPA in core courses' as covariates, no statistically significant difference was found between June and September scores for 'used, group non-mastery' knowledge. These two measures of student achievement are either producing overall significance in this statistical test, or are strongly correlated with the cause of the significance.

Table 4.35: F-Table for Used Group non-mastery

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	6.50	8	.81		
Used Group non-mastery	5.87	1	5.87	7.22	.03

Table 4.36: Means for Used Group non-mastery

TEST	MEAN	STD. DEV.
June	10.41	3.25
September	10.27	2.91
Difference	0.14	

These findings demand a conditional acceptance of the null hypothesis as repeated at the beginning of Section 4.3.2. The null hypothesis was accepted but with the following exceptions:

- Knowledge that was used in psycho-motor skill learning, but was not learned to group mastery level, when grouping by students' majors was considered;
- Knowledge that was used in psycho-motor skill learning (group mastery and group non-mastery levels combined), when grouping by students' majors is considered.

For these exceptions the alternative hypothesis, which states that grade point average in core courses will result in a statistically significant difference in retention patterns, was accepted.

In each case that the grouping by grade point average of students had resulted in a statistically significant interaction, the interaction had included knowledge that was used in the development of psycho-motor skills. In none of the three statistically significant interactions had 'not used' knowledge been a part of the interaction.

Knowledge that was used in skill development shows statistically significant losses when learned to an initial level that was relatively high but not high enough to fit the group mastery level criteria (see Section 3.3.2.4, page 71 for explanation of this criteria). Group mastery level used knowledge did not show an interaction that was statistically significant because in this case initial learning level was held relatively constant at a high level, reducing differences among groups. Group non-mastery level had a significant interaction because initial learning level was allowed to vary over a greater range, thus producing greater loss for some groups than others. This, of course, only holds true if some groups tend to have higher initial learning levels than others, as was the case here.

Knowledge that was *not* used in the learning of psycho-motor skills did not have these significant interactions when put through the same statistical analyses. This occurred in spite of the fact that overall, 'not used' knowledge showed significantly greater loss than 'used' knowledge. While the reason for this is not clear, it appears that students' achievement level, as shown by interactions between their Metalwork mark, their GPA, and their major, has a greater effect on retention rate of 'used, group non-mastery' knowledge than it does on retention rate of 'not used, group non-mastery' knowledge.

4.3.3 Mark in Metalwork 11 Course

Hypothesis 7 states that students with high Metalwork marks (HMM) in the Metalwork 11 course (top 25% of year average marks) will not retain a significantly different amount of all measured Metalwork 11 curriculum areas than students with low marks (LMM) in Metalwork 11 (bottom 25% of students). See definitions on page 8 for explanation of GPA system.

- H_O: $X_{diff_{HMM}} = X_{diff_{LMM}}$
- H_A: $X_{diff_{HMM}} \neq X_{diff_{LMM}}$

There was only one statistically significant interaction involving Metalwork mark. This interaction was between students' major, their year-end mark in Metalwork 11, and 'used, group non-mastery' knowledge and was closely related to interactions described in Section 4.3.2. The factor 'Mark' refers to students' year-end mark in Metalwork 11, divided into three levels (see Section 4.3, page 108 for description of this factor).

Table 4.37: F-Table for Used Group non-mastery by Major by Metalwork Mark Interactions

Source of Variation	SS	DF	MS	F	Sig of F
Within Cells	6.50	8	.81		
Used Group non-mastery x Major x Mark	13.84	1	13.84	17.04	.003

Table 4.38: Means for Used Group non-mastery by Major by Metalwork Mark Interaction

		JUNE		SEPT		
Major	Mark	Mean	N	Mean	N	Diff.
I.E.	Low	7.75	4	7.75	4	0
	Middle	10.00	5	10.40	5	+0.40
	High	-	0	-	0	-
Not Clear	Low	-	0	-	0	-
	Middle	11.43	8	10.13	8	-1.30
	High	13.50	2	12.50	2	-1.00
Academic	Low	16.00	1	13.00	1	-3.00
	Middle	-	0	-	0	-
	High	12.50	2	12.00	2	-0.50

Tables 4.37 and 4.38 show that significant interactions have occurred between means of the factors 'Major', 'Mark', and 'used, group non-mastery' knowledge, from June to September. Industrial Education majors experienced a slight gain in mean score, while Academic and Not Clear majors experienced loss ranging from 4% to 18.75%. Again, however, it is probable that this difference is related to the fact that Industrial Education majors had lower initial scores than did non-Industrial Education majors.

Interaction between 'mark' and 'major' may be partially a result of the small number of students falling into the Academic major and high mark group. With only one student, the fact that that student's score showed a large decrement (almost 20%) may have been enough to substantially increase an interaction effect. As described on page 97 in Section 4.2.4, when groupings by students' majors and summer skill practice were compressed into dichotomies, this interaction was no longer statistically significant. This would tend to indicate that an outlying score may have had a large effect on the small group that it fell into, producing significance that was an artifact of grouping.

The lack of statistically significant interactions involving Metalwork mark requires acceptance of this null hypothesis, and rejection of the alternative hypothesis. This alternative hypothesis stated that there would be a statistically significant interaction between students' Metalwork marks and all areas of the Metalwork curriculum.

4.3.4 Effects of Skill Practice During Retention Interval

Research has not provided a clear answer to the question of effectiveness of rehearsal on skill retention. Studies have found little effect [66,82], mixed effects [37], and significant effects [84,85,86]. Overall there appears to be slightly greater evidence on the side of rehearsal resulting in increased retention (see Section 2.2.4, page 25).

However, when summer skill practice was analyzed for its effects on that skill, no statistically significant results were found, nor were significant interactions with other factors found, with or without these other factors as covariates. These results relate to Hypothesis 8, which states that students who practice a psycho-motor skill (PR) during the retention interval will not retain that skill at a higher level than students who do not practice that skill (NPR) during the retention interval.

- H_O: $X_{diff_{PR}} = X_{diff_{NPR}}$
- H_A: $X_{diff_{PR}} < X_{diff_{NPR}}$

Because rehearsal was found to have no statistically significant effect on retention of a continuous psycho-motor skill, the null hypothesis was accepted and the alternative hypothesis was rejected, except in the case of one interaction. This interaction was one involving students' major, summer skill practice, and 'used', group non-mastery level knowledge, as shown in Table 4.15 (page 99) and Table 4.16 (page 99). In this case the null hypothesis is rejected, and the alternative hypothesis is accepted.

4.4 Summary

Each of the eight hypotheses have been addressed by the results of the statistical analysis described in this chapter. Where possible tentative explanations have been advanced. The next chapter will use these results to provide conclusions regarding the retention patterns of the various areas of the Metalwork 11 curriculum.

Chapter 5

Conclusions and Recommendations

5.1 Introduction

The results presented in Chapter 4 lead to several general conclusions. First, students forget a significant amount of knowledge over a period of three months of no study. Overall, this loss represented almost 7% of original learning. This loss cannot be explained in terms of general achievement in school, nor by students' majors. Another factor or factors were responsible for this loss. However, students do not experience loss of psycho-motor skills over the same length of time. Second, knowledge that is used in the development of psycho-motor skills does not experience loss, while knowledge not so used does experience loss. Third, knowledge learned to a high initial level suffers greater loss than knowledge learned to a lesser initial level.

This chapter will discuss these conclusions in greater detail. It will do so by restating each of the research questions that were introduced in Chapter 1, Section 1.2.1, followed by the conclusions that relate to each question. Possible applications of the findings to practice will then be suggested, followed by a discussion of the limitations of the study. The chapter will end with some suggestions for further research.

5.2 Research Questions and Corresponding Conclusions

1. Are continuous psycho-motor skills retained at a higher level than is the knowledge used in developing the skills?

As measured in this study, continuous psycho-motor skills are not retained at a higher level than is the knowledge used in developing these skills. Neither the skill nor the knowledge suffered statistically significant losses. This conclusion must be tempered by the fact that the measurement of these two types of learning (skill and knowledge) is very difficult, if not impossible, to equate exactly. Nevertheless, there is at least a very strong suggestion that using knowledge to learn a skill enhances retention of that knowledge to a level comparable with the level of retention of a psycho-motor skill.

2. Is the knowledge that is used in skill acquisition retained at a higher level than is knowledge not used in skill acquisition?

The results of this study lead to the conclusion that knowledge used in skill development is retained at a higher level than is knowledge that is not so used. The difference in retention is both statistically and practically significant. Retention loss of 'used knowledge' (4.40%), measured in percentages of original learning, is less than half of the loss experienced for 'not used knowledge' (9.38%). The decrement found for 'not used knowledge' cannot be explained in terms of achievement levels in Metalwork, achievement levels in core courses, students' majors, or amount of skill practice during the retention interval.

Ausubel and Youssef [9], studying the effects of repetition on retention of prose, concluded that repetition significantly improves retention. They offered several explanations in their conclusions. These explanations also provide possible reasons for the high retention of knowledge used in the development of skills.

- In using the knowledge to develop skills, the learner can relate "the potential meanings [the learned material] embodies to his structure of knowledge, thereby enabling actual or experienced meanings to eventuate or be consolidated" [9, p.149].

- Use of knowledge in skill development provides an opportunity to consolidate meanings initially established when the knowledge was acquired.
- Use of knowledge provides the learner with feedback as to the accuracy of his understanding of the knowledge. This "clarifies ambiguities, corrects misconceptions, and indicates areas of weaknesses" [9, p.149].

The results of this study point to the conclusion that exact repetition is not necessary. Significantly improved retention may be attained by having students use the learned knowledge in the development of a skill in an activity based learning situation. This not only improves the retention of the knowledge, but also results in the learning of a skill. Knowledge so used becomes resistant to forgetting at a level not significantly lower than the resistance to forgetting that continuous psycho-motor skills typically have.

3. How much of the difference in retention, between 'used knowledge' and 'not used knowledge', can be related to "mastery learning"?

When 'used' and 'not used' knowledge areas are also grouped according to level of initial learning, additional conclusions may be drawn. High initial levels of learning (termed 'group mastery' level knowledge) experience loss that is greater than loss experienced by knowledge that is initially learned to a moderate level (termed 'group non-mastery' level knowledge). This difference was statistically and practically significant, with loss of 'group non-mastery' level knowledge being only 40% of the loss experienced by 'group mastery' level knowledge (4.32% versus 10.66% of original level of learning).

Level of initial learning resulted in significant differences in retention of 'not used knowledge'. 'Not used, group mastery level' knowledge experienced greater loss than did 'not used, not group mastery level' knowledge. However, level of initial learning did not significantly affect the retention of 'used knowledge'.

In summary, "group mastery learning" does play a large role in the retention or loss of knowledge, especially so when only knowledge that is *not* used, in the development of psycho-motor skills, is considered. This loss of 'not used group mastery level' knowledge was found to be largely accounted for by the students' major, their summer practice of skills, their GPA in core courses, and their mark in the Metalwork 11 course. The retention loss was divided approximately equally among each of these four factors.

4. Does a predominantly academic background produce different retention patterns than does a predominantly non-academic background?

Retention patterns are not significantly affected by the amount of academic courses or Industrial Education courses taken by a student. Students' majors were found to have no statistically significant effect on retention of 'used knowledge', 'not used knowledge', 'group mastery level knowledge', 'group non-mastery level knowledge', and psycho-motor skills. Academic majors remembered, or forgot, approximately the same amount of material or skill that Industrial Education majors remembered, or forgot.

5. Do students with overall higher marks in core courses have a different rate of retention than do those with lower levels of achievement?

As defined in Chapter 1, Section 1.4 (page 8), core courses are those secondary school courses that all students must successfully complete in order to be eligible for graduation. For grades 10, 11 and 12 these are:

- Grade 10
  - Social Studies 10
  - English 10
  - Physical Education 10

  - Science 10
  - Mathematics 10

- Grade 11
  - Social Studies 11
  - English 11
  - Science 11

- Grade 12
  - Social Studies 12
  - English 12

- Consumer education must be taken in Grade 9, 10, 11, or 12.

Overall, students' levels of achievement in these core courses did not affect retention patterns. Students with higher marks in core courses did not forget significantly different amounts of 'used', 'not used', 'group mastery', or 'group non-mastery' knowledge, or psycho-motor skills than did students with lower marks in core courses.

6. Do students with overall higher marks in Metalwork 11 have a different rate of retention than do those with lower marks?

Level of achievement in Metalwork 11 did not make a significant difference in the rate of retention of 'used', 'not used', 'group mastery', or 'group non-mastery' knowledge, or psycho-motor skills. Students who did poorly in Metalwork 11 still retained approximately the same percentage of original learning as those who did well in Metalwork 11.

7. Does skill practice during the retention interval affect retention levels?

Interactions between skill practice and skill retention were not statistically significant. The conclusion, based on this study, is that skill practice during the interval does not produce significantly higher levels of retention of a continuous psycho-motor skill.

While the conclusions of the research that was reviewed (see Section 2.2.4, page 25) present no definitive answer regarding the effects of practice during the retention interval, it would appear that two factors should be considered in the conclusions of the present study.

First, the retention period is only three months in this study. It may well be that practice during a longer interval, of perhaps 1 to 5 years, would have a significant effect on retention [84,85,86]. Second, the present study is measuring the retention of a continuous skill, as opposed to a procedural skill. Continuous skills are generally retained at a higher level than are procedural skills [1,5,61,62,78], so it may well be that practice during the interval may have a positive effect on the retention of a procedural skill.

5.3 Applications of Findings to Practice

This section will discuss possible applications of the conclusions of this study, to practice in the classroom or laboratory.

5.3.1 Use of Knowledge

The present study provides evidence that learned material will be more resistant to forgetting if the learned material is used in an activity-based skill development. This has particular applications to Industrial Education courses that endeavor to teach psycho-motor skills as well as factual knowledge.

Factual knowledge acquired in a verbally based learning situation has been found to suffer high losses due to forgetting (see Section 2.3, page 32 for a detailed review of retention of academic learning). If this factual knowledge is to be retained, then it is important to develop, or implement, the curriculum in such a way that the knowledge is used in the development of skills. If this is done, loss due to forgetting will be minimal.

It is of questionable value to devote a large portion (and perhaps even a small portion) of instructional time to the teaching of content material that will not be used by the student. In Metalwork, such topics might include 'the history of development of the engine lathe', or perhaps 'methods of production of steel from iron ore'. Unless an instructor finds ingenious ways of using this material in an activity-based setting, loss to forgetting will likely be rapid.

5.3.2 Group Mastery Level Learning

Teaching to a high initial level of achievement is, intuitively, a positive goal in education. However, the results of the present study indicate negative, as well as positive, effects of group mastery level learning.

If high levels of retention are very important, group mastery learning may be considered as a means to that end. However, it is not a particularly efficient means, because the amount of learning that is forgotten increases as the initial learning level increases. Nevertheless, teaching to group mastery level is still a means to attaining higher retention because as more is learned, and more is forgotten, more learning is also retained.

One method of making group mastery level learning an efficient means of increasing retention is to ensure that the learning is used in the development of skills. In this way the high initial level of learning does not suffer losses significantly greater than the minimal loss found for knowledge learned to a low or moderate initial level.

5.3.3 General School Achievement

On the basis of the results found in this study, it is not necessary to provide extra review for students who generally do more poorly in core courses such as English or Social Studies. Retention is not poorer for these students, rather retention is based on level of initial learning of the material in question. The same holds true for students who do poorly in Industrial Education courses. Marks in any of these courses should not have an effect on the amount of review or extra study required of student doing poorly in core courses. The Industrial Education teacher may expect forgetting rather on the basis of original level of achievement and the amount of use of the knowledge learned.

5.3.4 Retention of Psycho-Motor Skills

The continuous psycho-motor skill that was measured in this study experienced no significant loss, in fact a gain of 10.73% was found, but the gain was not statistically significant. Nevertheless, it does show that continuous skills are retained extremely well.

Skills learned previous to entry into an Industrial Education course require very little review, if any. Certainly time would be better spent reviewing material that had been previously taught, but not used in a skill development. This is especially true where that knowledge is required to be learned to a high level, but has not been used in an activity-based skill learning situation.

Once a student has learned a skill to a satisfactory level, that skill does not need further extensive practice to be maintained well. The student may neglect that skill for a time in order to concentrate on other learning, without being overly concerned about loss of the original skill.

5.3.5 Skill Practice During Periods of No Instruction

Practicing a skill during a retention interval does not significantly improve a student's skill retention, according to the findings of this study. Surprisingly, students who practiced in the interval, in the present study, actually experienced slightly *less* gain in the interval than did students who did not practice. While this difference in retention was not statistically significant, it was in a direction that would not be expected. Regardless of the actual difference, it is apparent that continuous psycho-motor skills are resistant enough to loss that practice does not make a significant difference.

In view of the caveats stated in the discussion of Research Question 7 (page 123), it should be noted that this recommendation is based on a continuous skill, over a period of approximately three months. A significantly longer retention period may have required practice of the skill in order to reduce forgetting to a minimal level. Also, a procedural skill may have benefited from practice in the retention interval.

5.4 Limitations of the Study

The present study had several limitations. While these limitations did not invalidate the results of the study, they did limit the generalizability of the results. Removal of these limitations would have broadened the scope and generalizability of the present study. This section will list these limitations.

- The sample was made up of 22 subjects. This small sample size resulted in some restrictions, especially when analyses of different groups resulted in groups having sizes of 1 to 3 subjects, and some groups with *no* subjects. For this reason some findings may have been missed, or perhaps results were found that were an artifact of the small sample size. Outliers may have had an effect on the statistical analyses that was misleading.

- The sample was obtained from one school, and one teacher. While this had great benefit in eliminating certain nuisance variables, it had the effect of reducing generalizability. Had the sample been drawn at random from a large number of schools the results would have been much more certain to generalize more broadly.

- A continuous psycho-motor skill was chosen as a sample of psycho-motor skills. This was done because a procedural skill is more similar to verbally based learning than is a continuous skill. However, it did limit the study to results based on a continuous skill, where perhaps additional or even different results may have been obtained if a procedural skill had been chosen as a sample of psycho-motor skills.

- The retention interval was determined primarily by the length of the summer vacation. This limited the study to one measurement of retention. Measuring retention at perhaps 6, 12, and 24 months would have added to the study, provided additional insight into the factors that affect retention of knowledge and skills in the Metalwork 11 curriculum.

- The present study was limited to skills and knowledge learned in the Metalwork 11 curriculum. Additional knowledge would have been gained, and generalizability improved had the study included skills and knowledge from other grade levels in Metalwork, or had also included other Industrial Education courses such as Woodwork.

- No pretest was given to the subjects prior to their entry into Metalwork 11. It is possible that students already knew some of the measured skills and knowledge before they entered Metalwork 11. To some extent, then, the measurement of knowledge and skills went beyond that learned in Metalwork 11. It is quite possible that knowledge and skills that have been learned and remembered for several years have a different retention pattern than knowledge and skills gained during the year that preceded final testing.

- Students attitude and feelings toward the different aspects of the Metalwork 11 curriculum was not measured. It is possible that attitude toward the factual knowledge aspect of the course may have been different from students' attitude toward the psycho-motor aspect of the course, and that this difference had an effect on retention of these types of learning.

5.5 Recommendations for Further Study

Many of the following recommendations stem directly from the limitations of this study as detailed in the previous section. Further research could do much to compensate for these limitations and to extend the knowledge gained by the present study.

1. A similar study but using a larger sample, drawn at random from several schools, would be valuable to provide additional data to confirm or refute the conclusions drawn in the present study. There would be difficulties in controlling extraneous variables in this larger sample, but they are difficulties that could be overcome.

2. A longer term study would be beneficial in finding out if the retention advantages of use of knowledge are long lasting, or if they change over time. This study should be a minimum of 12 months. Again, there are greater difficulties in maintaining a sample over an extended period of time, but the knowledge gained would be valuable.

3. Similar retention studies could include a pre-test, as well as a post-test and a retention test. This would identify the learning that took place during the time

of study, versus knowledge or skill that was learned to some extent prior to the start of the study. The retention effects of this variable, and the interactions between time of learning and the other variables, would provide additional practical knowledge that could benefit the classroom teacher.

4. A study could be conducted that was similar in design but was carried out with a sample drawn from Industrial Education courses other than Metalwork. Information gained here would give guidance as to the generalizability of the results of the present study.

5. A study that determined the retention effects of using knowledge in a variety of activity based learning situations would be valuable. It may or may not be that psycho-motor skill learning is best for enhancing the knowledge that is used.

6. A study that used qualitative measurement as well as quantitative measurement might be employed to determine the effects of student attitudes toward various types of learning, on retention of those various types of learning. Measurement of change in attitude over the retention period may also lead to results that can supply practical knowledge to the classroom teacher.

7. Industrial Education courses teach more than knowledge and skills. Problem solving and critical thinking skills are a natural and desirable part of each curriculum. The retention of these cognitive skills is a topic that requires more study.

Retention of all types of learning must be seen as of great importance as educators seek to provide a useful, beneficial education to their students. Without retention of learning, the learning will not serve the needs of the students. Studies of retention in the area of Industrial Education are few in number, far fewer than the importance of the topic would merit.

Many practical, beneficial results can be gained from a series of studies that investigate the different variables that affect retention. The suggestions for further research that are presented here are just suggestions. Researchers will not have to look far to find other areas of Industrial Education that would benefit from careful research into the effects of practice on learning. The present study, in investigating the retention rates of several types of learning, has provided a few conclusions that may be of use in the classroom. Further research would be useful in providing more knowledge concerning the retention of the learning outcomes of the Industrial Education curricula.

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Appendix A

Weld Pad Scoring Guide

There are six characteristics that were scored for each welding pad. Each characteristic was scored independently, then totaled to produce the overall score for each pad.

The characteristics were:

Bead Width	/4
Bead Overlap	/4
Cross Sectional Shape	/4
Ripple Shape and Spacing	/4
Amount of Spatter	/3
Crater Location and Filling	/3

Each of these separate characteristics will be discussed briefly, and photographs of each possible score will be presented in order to provide scoring criteria.

During the scoring procedure all the pads were rated on only one characteristic at a time. Following the rating of one characteristic, the pads were shuffled and all pads were then rated on the next characteristic. Pads were shuffled in an attempt to avoid a 'response set' by raters. For reliability purposes it was considered important to score only on the basis of one characteristic at a time, and to avoid, as much as possible, interference by the other characteristics.

If the maximum possible score was four, then the pads were placed into four groups, then scored from 1 out of 4 for the group that least met the characteristic, to 4 out of

4 for the group that best met the characteristic. The pads were then to be regrouped based on the quality of the next characteristic, and then that characteristic was scored. The procedure for scoring a characteristic valued at three was the same, but used three groups as opposed to four.

Some pads had a splash of red paint on the under-side. These pads were included with the others during the grouping and scoring. The paint was not visible during the rating process, but following the rating the pads were turned over and the scores were recorded on separate score cards, labelled 'paint' and 'no paint'.

Refer to the photos and criteria description, on the next page, for the scoring of each characteristic.

A.1 Bead Width

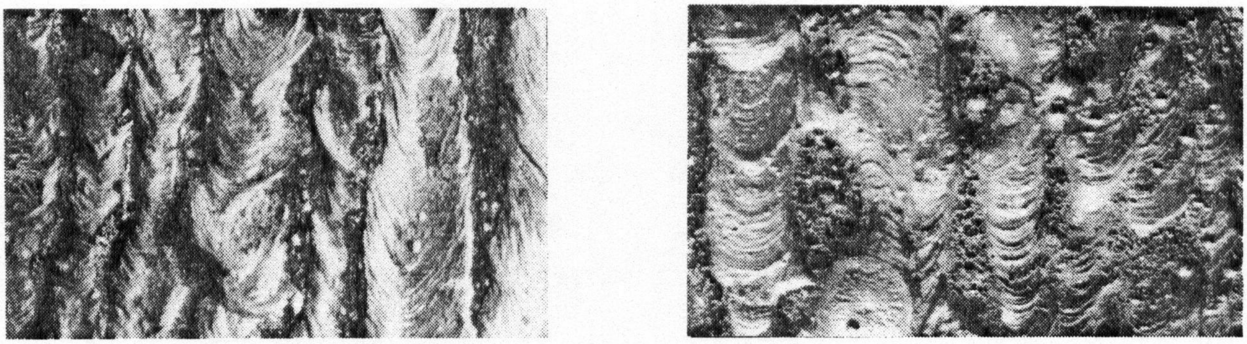

Figure A.2: Bead Width score: 1 out of 4.

These pad segments have beads that vary greatly in width. The width of some bead segments is over 100% greater than the width of other segments on the same pad. Pads may also be scored 1 out of 4 for this characteristic if bead width is not between 6 mm and 13 mm.

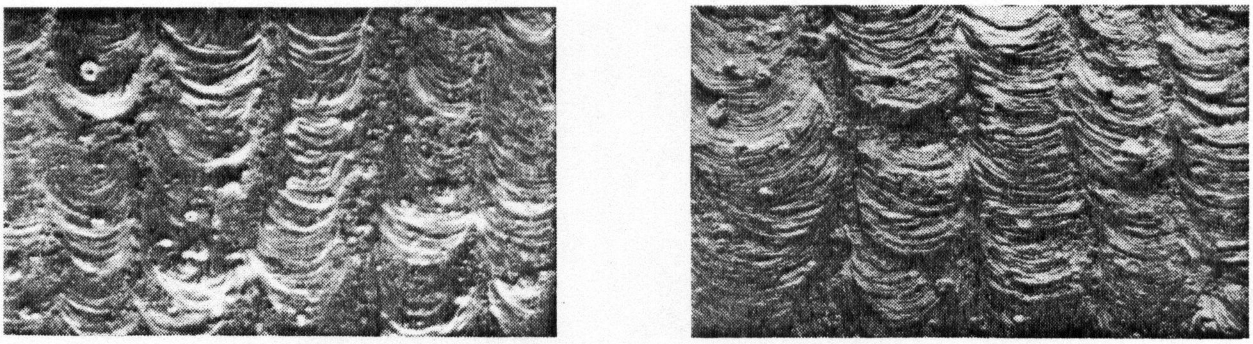

Figure A.3: Bead Width score: 2 out of 4.

While these pad segments contain beads that vary in their width, the variation is not great. Beads segments may be over 50% but less than 100% greater than the width of other bead segments. Pads may also be scored 2/4 if average bead width is not between 8 mm and 11 mm but is within 1.5 mm of these boundaries.

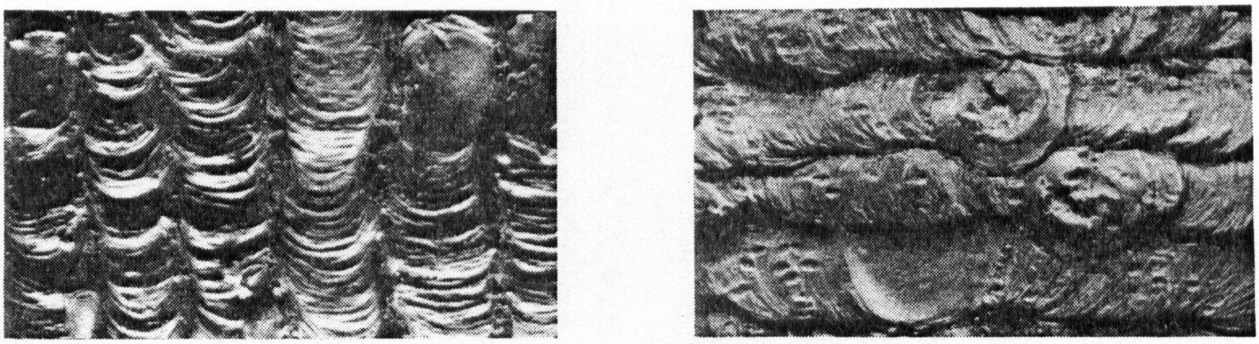

Figure A.4: Bead Width score: 3 out of 4.

Bead width here is quite consistent, but irregularities cause bead width of some segments to be over 25% but less than 50% greater than other segments. Average width is between 8 mm and 11 mm.

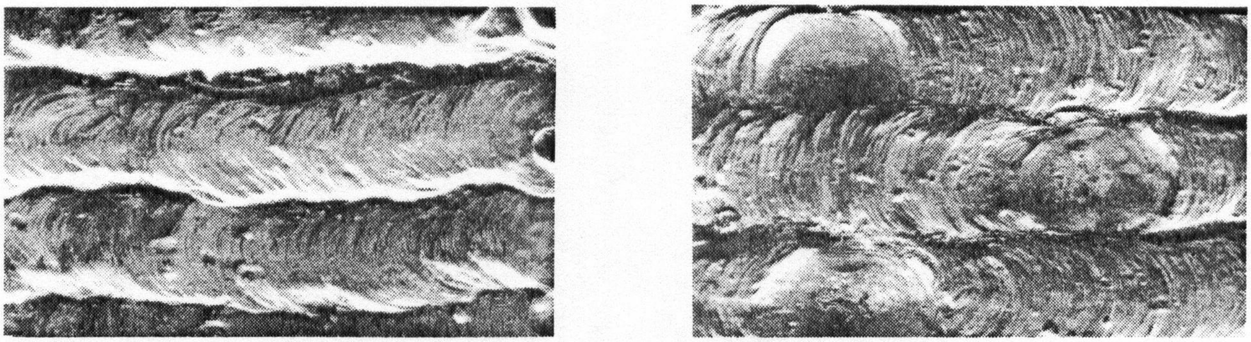

Figure A.5: Bead Width score: 4 out of 4.

These beads have very consistent width, varying less than 25%. Overall width is between 8 mm and 11 mm.

A.2 Bead Overlap

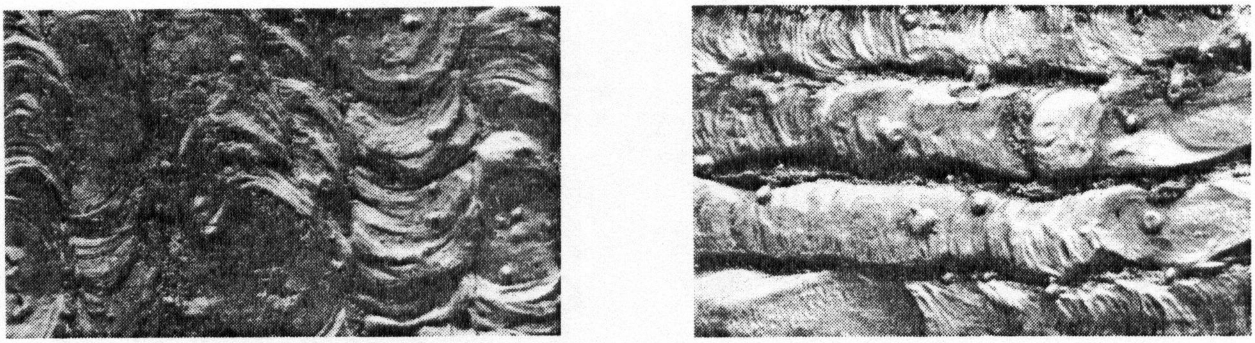

Figure A.6: Bead Overlap score: 1 out of 4.

These pads have different faults. The pad above left has beads that overlap very inconsistent amounts, with one bead crossing another 100%. Above right is a pad that has virtually no overlap at all.

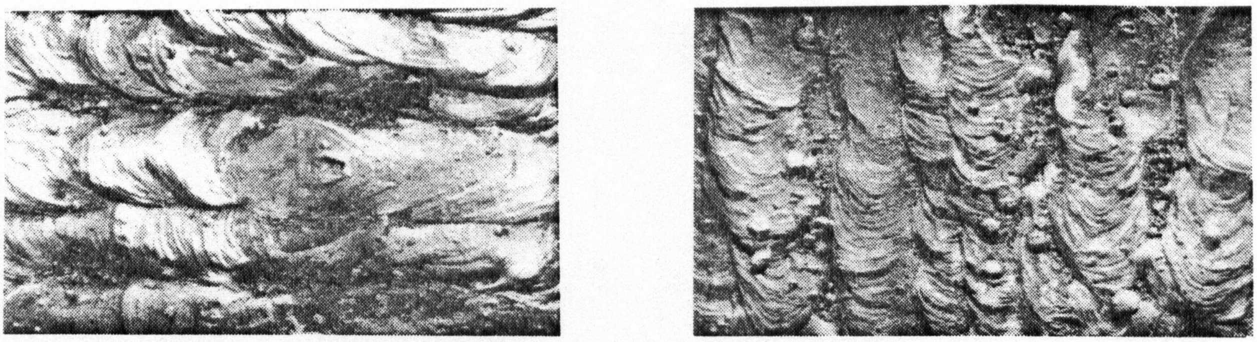

Figure A.7: Bead Overlap score: 2 out of 4.

Overlap here ranges from 0% to 75%. Generally there is some overlap, but consistency is poor.

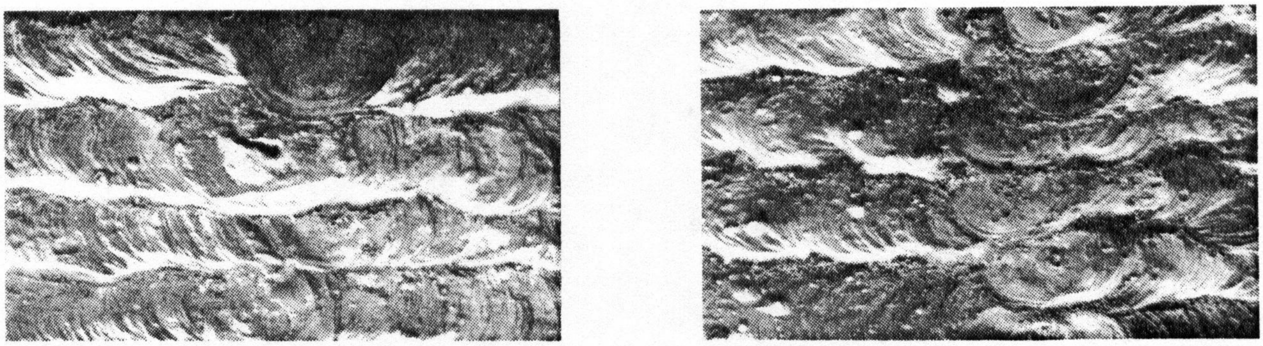

Figure A.8: Bead Overlap score: 3 out of 4.

Bead overlap varies from almost nothing in a few places to about 50% in other places, but in general is fairly consistent.

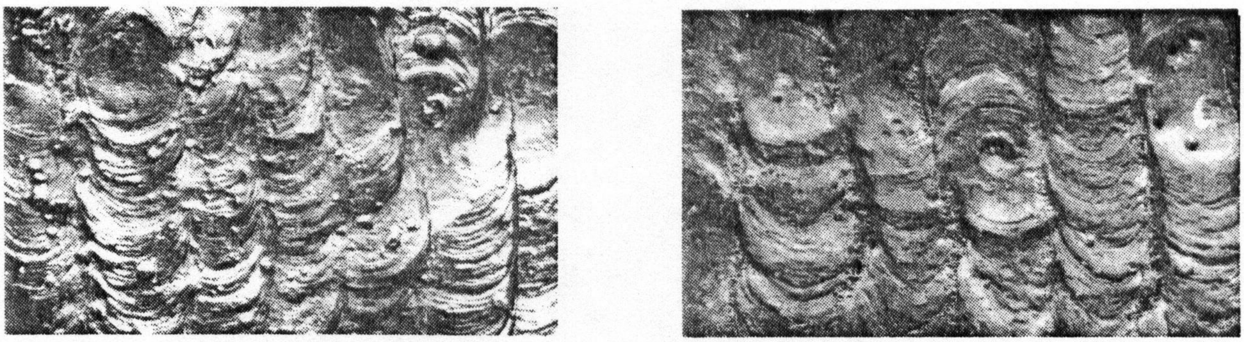

Figure A.9: Bead Overlap score: 4 out of 4.

Pads that score 4 for bead overlap have overlap that varies less than 25% and ranges from 10% to 30% of bead width.

A.3 Cross Sectional Shape

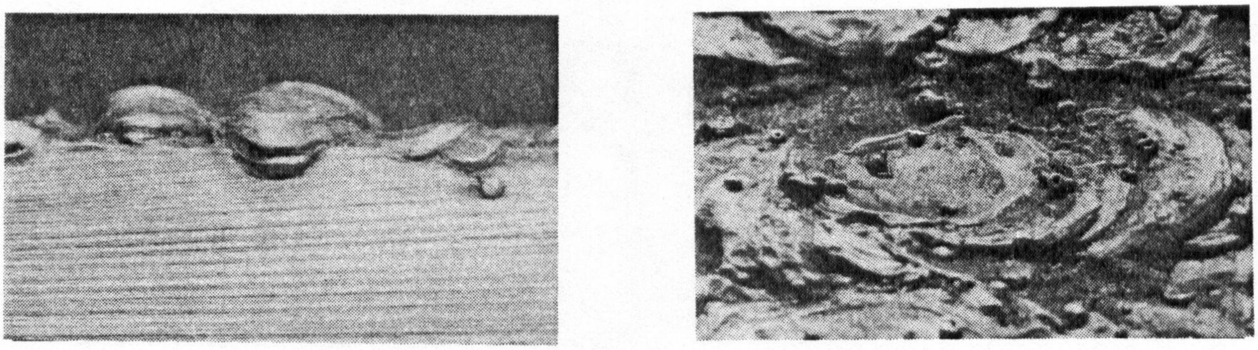

Figure A.10: Cross Sectional Shape score: 1 out of 4.

The end view at left (above) clearly shows a great difference in the height to width ratio of the weld beads. Height should be about 20% of width, but this category shows this ratio to be closer to 75% in some cases to 5% in other areas (see above right).

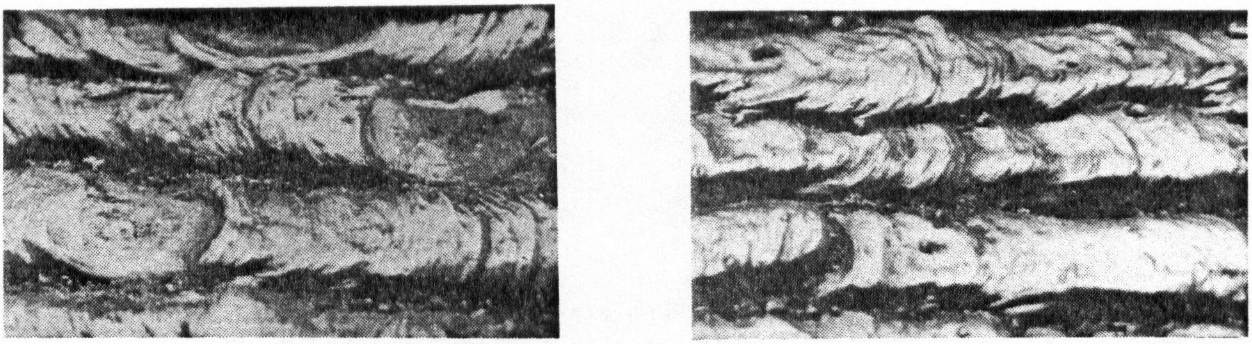

Figure A.11: Cross Sectional Shape score: 2 out of 4.

Average height is between 5% and 15% of width (too flat), or between 40% and 75% of width (too high).

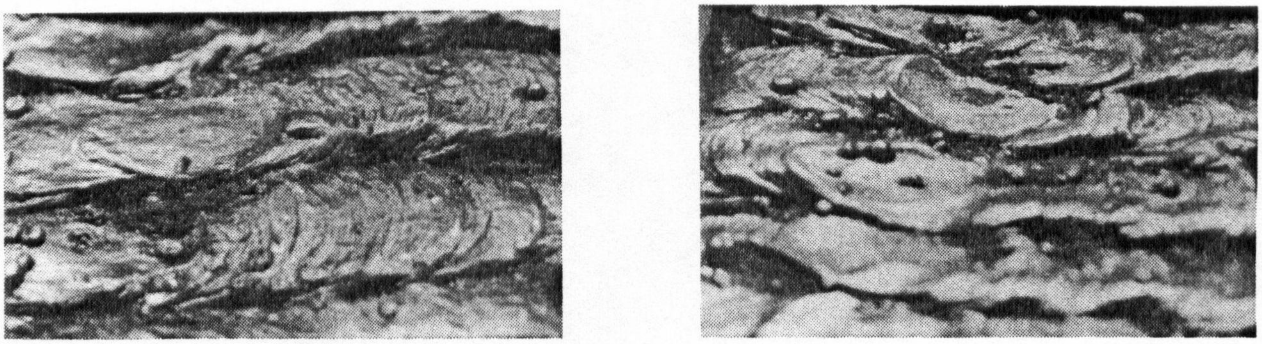

Figure A.12: Cross Sectional Shape score: 3 out of 4.

Beads are quite close to a desirable ratio of height to width. The average height is between 30% and 40% of width or between 15% and 20% of width.

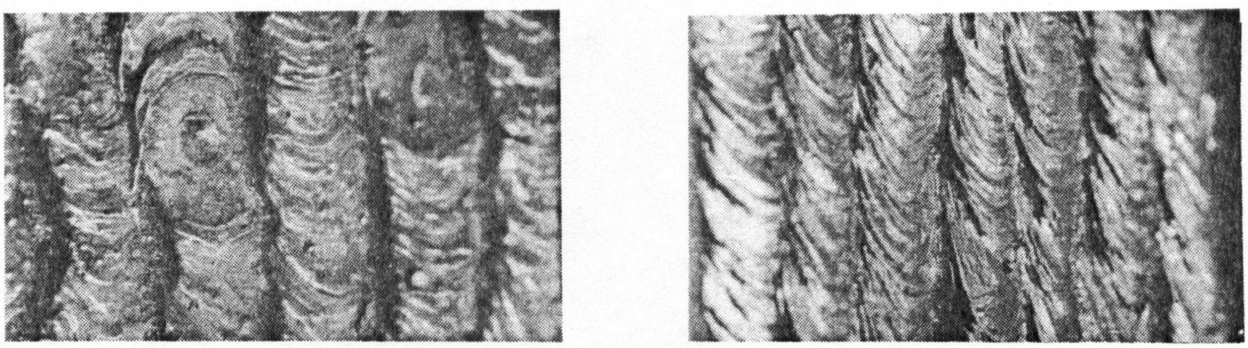

Figure A.13: Cross Sectional Shape score: 4 out of 4.

These beads have consistent height which is between 20% and 30% of bead width.

A.4 Ripple Shape and Spacing

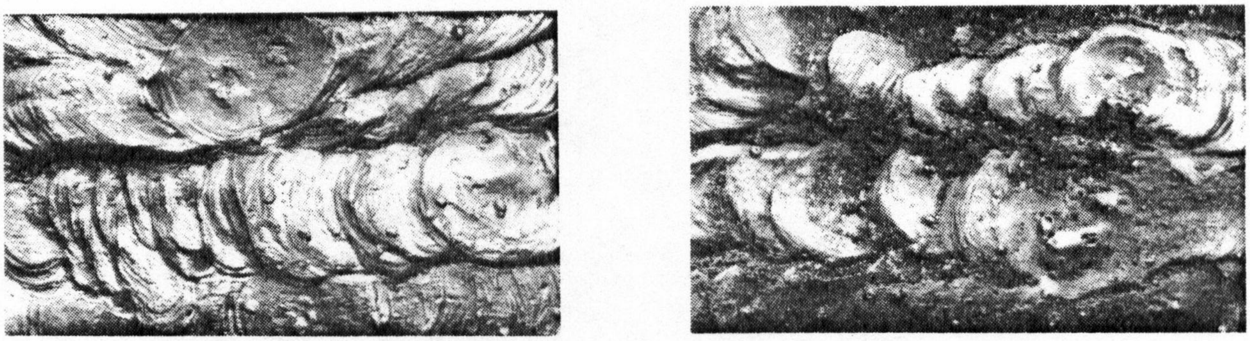

Figure A.14: Ripple Shape and Spacing score: 1 out of 4.

The ripple pattern here is very irregular. Some of the ripples are very large, some very small. Some are semi-circular in shape, others are very flat or very pointed.

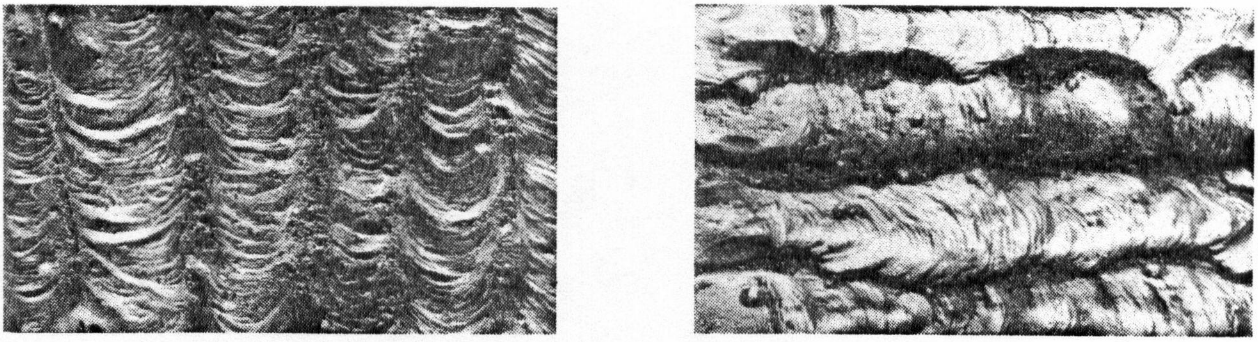

Figure A.15: Ripple Shape and Spacing score: 2 out of 4.

Consistency is improved here, but significant variation remains both in spacing and shape of ripples.

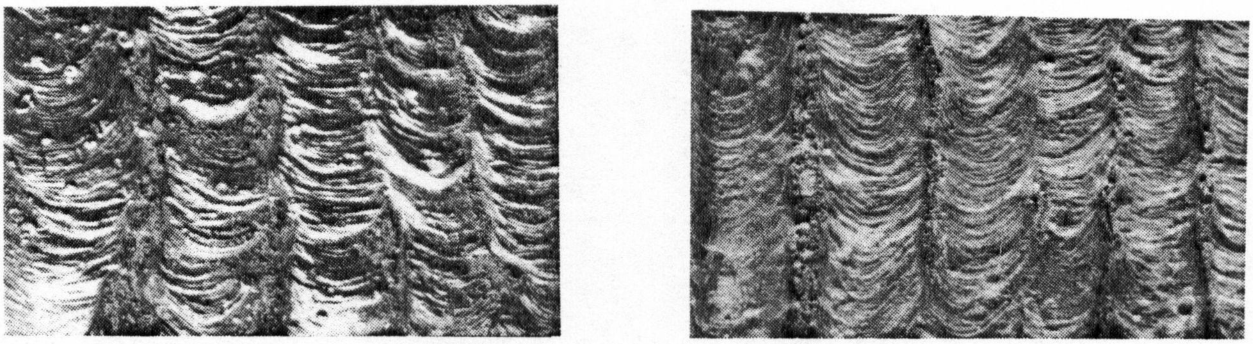

Figure A.16: Ripple Shape and Spacing score: 3 out of 4.

Small variations are evident in shape and spacing of ripples, but no large variations can be found.

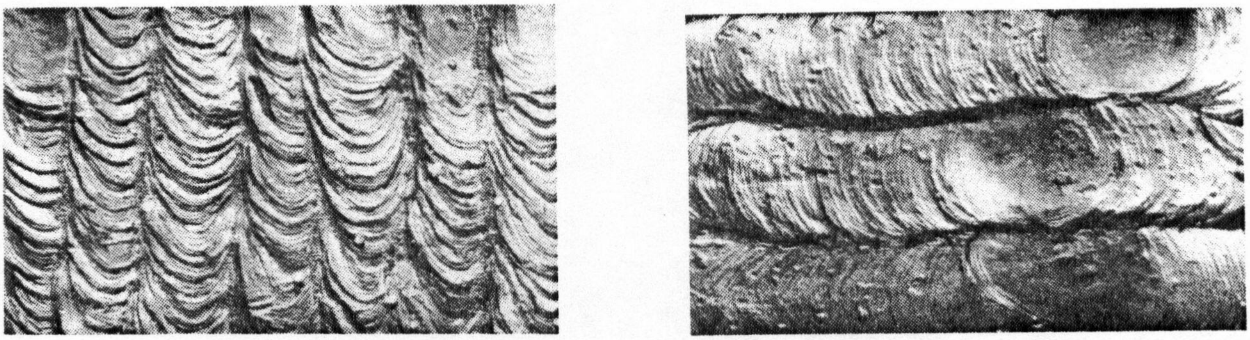

Figure A.17: Ripple Shape and Spacing score: 4 out of 4.

Although the ripple patterns of these two examples vary, each shows a very consistent pattern, with the shape being almost exclusively semi-circular.

A.5 Amount of Spatter

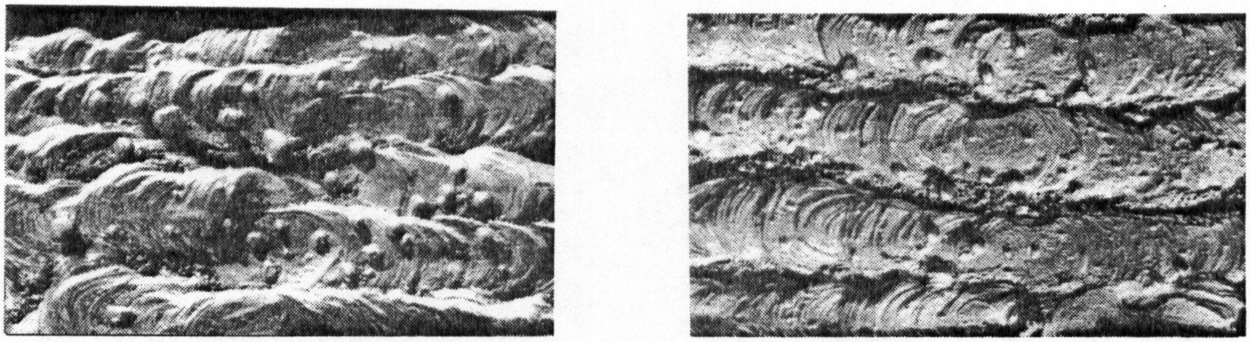

Figure A.18: Spatter Amount score: 1 out of 3.

Excessive spatter can be seen on this type of bead. More than 20 large (approx. 1.5 mm) droplets of metal can be counted on the pad.

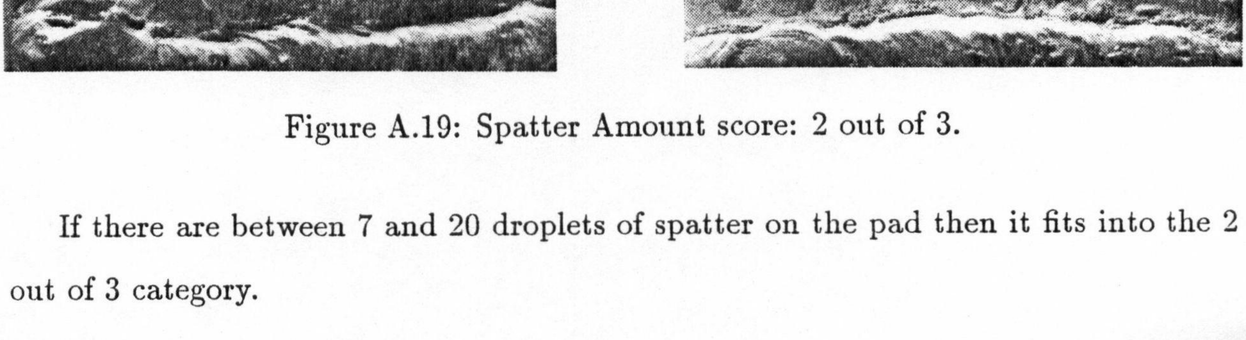

Figure A.19: Spatter Amount score: 2 out of 3.

If there are between 7 and 20 droplets of spatter on the pad then it fits into the 2 out of 3 category.

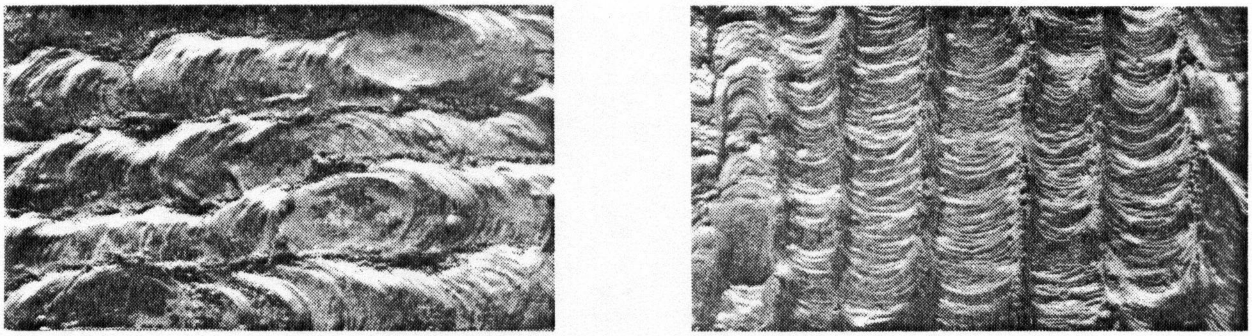

Figure A.20: Spatter Amount score: 3 out of 3.

Minimal spatter is evident here, with less than 7 significant droplets on each pad.

A.6 Crater Location and Filling

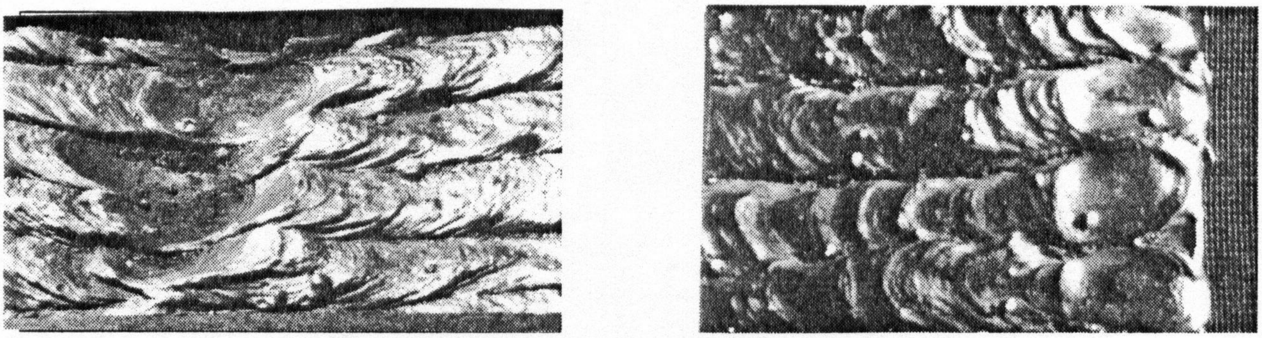

Figure A.21: Crater Location and Filling score: 1 out of 3.

The craters are very concave (left) or are at the end of the bead (right) as opposed to anywhere but the end. This score should also be given if the craters have extreme porosity.

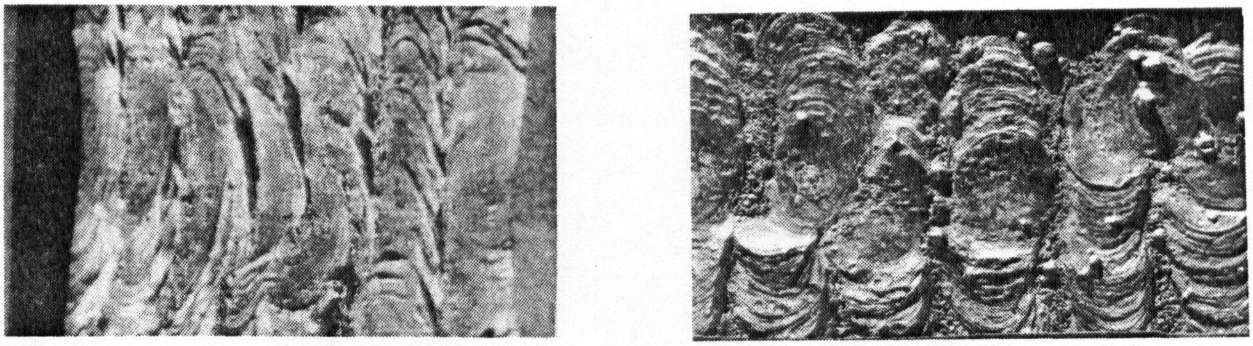

Figure A.22: Crater Location and Filling score: 2 out of 3.

The craters are moderately concave (left), or are not aligned (right). There may be some porosity in the craters.

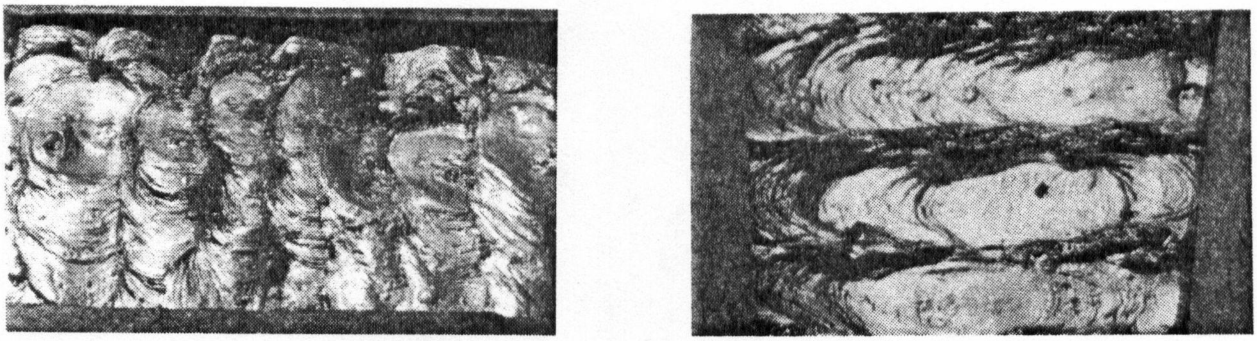

Figure A.23: Crater Location and Filling score: 3 out of 3.

These craters are filled to a height equivalent to that of the beads. Crater porosity is minimal.

Appendix B

Multiple Choice Instrument

INSTRUCTIONS

1. Do not write on or mark the question sheets.
2. Answer all questions.
3. **Read all the choices**, then choose the best one.
4. Darken in ONE circle on the answer sheet, opposite the question number.
5. Clearly cross out or erase any mistakes.

1. A glazed wheel is one that ...
   A) has been dressed smooth with a diamond wheel dresser
 * B) has become dull
   C) has been coated with silicon to produce a smooth surface
   D) shines when subjected to ultra-violet light
   E) is used on ferrous metals only

Proportion Correct: June .682; September .682

2. Grinding wheel 'structure' is talking about ...
   A) size of the abrasive grains
 * B) spacing of the abrasive grains
   C) hardness of the grains
   D) hardness of the bond
   E) type of bond used

Proportion Correct: June .636; September .545

The following 2 questions refer to this grinding wheel label:
A 60 M 8 V

3. The 'A' refers to ...
* A) kind of abrasive
  B) size of grains
  C) kind of bond
  D) structure of the wheel
  E) grade, or hardness of the bond

Proportion Correct: June .455; September .455

4. The 'V' refers to ...
  A) abrasive size
  B) wheel structure
  C) hardness or grade of bond
* D) bond type
  E) abrasive type

Proportion Correct: June .682; September .636

The remainder of the questions do NOT refer to the grinding label.

5. Artificial abrasives are used more than natural abrasives because ...
  A) natural abrasives are becoming difficult to obtain
  B) natural abrasives are now more costly
  C) natural abrasives are difficult to bond together
* D) artificial abrasives are more uniform in hardness and grain size
  E) artificial abrasives have a tendency to become harder with use, a process called "work hardening"

Proportion Correct: June .273; September .227

6. The action of a grinding wheel is best described as a ...
* A) cutting action
  B) rubbing process
  C) wearing-away action
  D) melting away (of small particles)
  E) pitting action

Proportion Correct: June .818; September .773

7. When ideal grinding conditions exist, a grinding wheel ...
* A) keeps itself sharp by dull grains being forced out exposing sharp ones
B) gradually becomes glazed, producing smooth surfaces
C) will not wear down
D) generates enough heat to melt out small metal particles
E) will not generate any heat
Proportion Correct: June .318; September .409

8. Using the shop method of calculating, which of the following answers would be the right rpm for turning the outside diameter of a 6" aluminum wheel using a H.S.S. tool bit?
A) 50 rpm
B) 75 rpm
* C) 200 rpm
D) 280 rpm
E) 475 rpm
Proportion Correct: June .364; September .318

9. If you were to machine a 6" diameter piece of steel in the lathe, which speed setting should you choose?
A) 50
* B) 67
C) 400
D) 1800
E) 2400
Proportion Correct: June .773; September .591

10. Which is **NOT** an advantage of forging?
A) it produces stronger products than casting does
B) it is cheaper than machining some objects
C) less waste
* D) it produces exactly sized products
E) none of the above are advantages
Proportion Correct: June .955; September .864

11. Which one of the following would cause shrinkage hollow in an aluminum casting?
    A) aluminum too hot when poured
    B) sand not adequately mulled
*   C) gate (ditch between reservoir and casting cavity) too shallow or long
    D) sand had too much oil mixed in it
    E) pattern was poorly designed

Proportion Correct: June .864; September .909

12. A split pattern is a pattern ...
    A) that has dried out and finally opened at the glue joint
    B) that is made from pine of straight grain by splitting it into its general shape, then finish by carving with chisels,etc.
*   C) that is made in two pieces
    D) none of the above

Proportion Correct: June .727; September .591

13. A slope on a pattern to help it come out of the sand is referred to as the ...
    A) drag
    B) drift
*   C) draft
    D) bevel
    E) fillet

Proportion Correct: June .909; September .636

14. The cut-off grinder is good for cutting...
    A) none of the following materials
*   B) all of the following materials
    C) light tubing
    D) hard steel
    E) rod up to 7/8"

Proportion Correct: June .773; September .727

15. The MAIN reason that wide flat bars are raised up on one edge when cutting them in the metal-cutting band-saw is ...
    A) it cuts faster than if it were flat
    B) a faster cutting speed can be used in the position
    C) there is much less chance of vibration
    D) the blade does not overheat that way
*   E) the teeth are less likely to plug up and jam

Proportion Correct: June .500; September .409

16. What is the minimum width of metal that should be cut in the bandsaw?
    A) 1/4"
*   B) 1/2"
    C) 7/8"
    D) 1"
    E) 1 1/2"

Proportion Correct: June .636; September .409

17. When a micrometer is set to 0.437" the number on the thimble that will line up with the reference line on the barrel will be ...
    A) 3
    B) 7
*   C) 12
    D) 17
    E) 37

Proportion Correct: June .864; September .909

18. $\frac{1.495}{1.500}$ means ...
    A) 1.495 is the best possible size
    B) the part has to be either 1.495 or 1.500
    C) the part has to be 1.495 at one end and 1.500 at the other end
*   D) anywhere between 1.495 and 1.500 is okay
    E) you don't have to be very careful because it doesn't have to be an exact size

Proportion Correct: June .500; September .273

19. A vernier slide caliper is set to read 3.641. Which line on the vernier scale would line up with a line on the main scale?
    A) 1
    B) 6
* C) 16
    D) 41
    E) 64

Proportion Correct: June .545; September .500

20. In counter-boring the idea is to ...
    A) make a flat surface at right angles to the tool holder
* B) enlarge and deepen an already drilled hole, the new hole having a flat bottom
    C) countersink an already drilled hole, for a flatheaded bolt
    D) a fairly fast R.P.M. should be used as this helps to clear away the chips
    E) none of these

Proportion Correct: June .727; September .591

21. In spot-facing ...
    A) the tool must be raised to cut
    B) counter sinking is the main idea
    C) the idea is to bore a certain depth hole
* D) the idea is to make a flat circular surface
    E) none of the these

Proportion Correct: June .591; September .773

22. Prior to reaming a hole, a hole is drilled which is ...
* A) 1/64" under the reamer size
    B) 1/16" under the reamer size
    C) the same size as the reamer
    D) slightly over the reamer size in case the drill is worn and cutting undersize
    E) the tap drill size of the reamer

Proportion Correct: June .591; September .682

23. When drilling a one inch hole on a lathe, the speed (RPM) should be set to ...
    A) 180
    B) 200
* C) 300
    D) 400
    E) 800

Proportion Correct: June .818; September .591

24. The 4-jaw chuck is called ...
* A) an independent chuck
    B) a universal chuck
    C) a Jacob's chuck
    D) a metal chuck
    E) a self-centering chuck

Proportion Correct: June .591; September .727

25. A tapered mandrel is used to ...
* A) hold some parts for turning between centers
    B) push shafts out of worn bearings
    C) act as studs in certain machines
    D) true up work in a 4 jaw chuck
    E) set a lathe for taper turning

Proportion Correct: June .318; September .182

26. When threading on the lathe...
    A) the compound is set to feed in at 90^o to work
* B) the half-nut lever is disengaged after the toolbit has been withdrawn from the work piece at the end of each cut
    C) the crossfeed is turned in slightly for the feed after each pass
    D) the tool bit point should be set lower than the centre of the work piece
    E) the compound slide crank is returned to '0' after each pass

Proportion Correct: June .364; September .182

27. The jaws on a 3 jaw universal chuck are opened or closed ...
    A) by a left hand thread on the large lathes and by a scroll (spiral) thread on the small lathes
    B) by a left hand thread on small lathes and right hand thread on the 2 large lathes
    C) by a left hand acme thread on all lathes
*   D) by a scroll (spiral) thread on all lathes
    E) by a right square thread on all lathes

Proportion Correct: June .955; September .955

28. The part of the tool bit that should touch the work in the lathe first is...
    A) the side
*   B) cutting point or edge
    C) front face
    D) the bottom edge
    E) none of the above

Proportion Correct: June .591; September .636

29. What is a good average feed on a lathe?
    A) .004
*   B) .007
    C) .010
    D) .040
    E) .070

Proportion Correct: June .500; September .318

30. Using the lathe speed formula, what RPM would the lathe be set to when machining 1/2" mild steel?
    A) 200
    B) 300
    C) 400
    D) 600
*   E) 800

Proportion Correct: June .636; September .636

31. Which statement is **FALSE** (referring to lathework)?
* A) roughing cuts should not be deep cuts
  B) more time is spent on finish cuts for accuracy
  C) about 1/32" of metal should be left after roughing cut, for finish cut
  D) the idea of roughing cut is to remove maximum metal quickly
  E) finish cuts use higher rpm than rough cuts

Proportion Correct: June .545; September .545

32. Choose the correct statement about centre-drilling in the lathe (part made of mild steel) ...
* A) use 1,000 rpm (about)
  B) reverse the lathe when withdrawing drill
  C) advance the drill in very slowly
  D) use special center-drilling oil
  E) center-drill in the smaller lathes only since the larger ones don't turn fast enough

Proportion Correct: June .500; September .409

33. A vertical milling machine has...
  A) vertical power feed
  B) a vertical head that bolts to the horizontal arbor
* C) no horizontal arbor
  D) a vertical and horizontal arbor
  E) none of the above

Proportion Correct: June 1.000; September .955

34. Which is **NOT** a type of milling machine?
  A) vertical
  B) horizontal
* C) angular
  D) combination

Proportion Correct: June .182; September .455

35. What is the speed formula for milling?
* A) $\frac{300}{dia.of cutter}$
  B) $\frac{400}{dia.of cutter}$
  C) $\frac{300}{dia.of work}$
  D) $\frac{400}{dia.of work}$
  E) $\frac{700}{length of cut}$

Proportion Correct: June .864; September .864

36. Most milling machines are of what main type?
  A) carriage and ways
* B) knee and column
  C) column and ways
  D) table and knee
  E) table and column

Proportion Correct: June .409; September .318

37. To increase heat, a Basic Oxygen furnace uses...
  A) coal
  B) coke
  C) a gas flame sweeping from side to side
  D) a blast of hot air
* E) pure oxygen

Proportion Correct: June .636; September .682

38. A material which contains iron as a base element is called ...
  A) an alloy
  B) ferrite
  C) non-ferrous
* D) ferrous
  E) pure iron

Proportion Correct: June .636; September .727

39. What is an alloy?
* A) two or more metallic elements (other than carbon)
  B) a metal that is a pure element
  C) any metal that has carbon in it
  D) any metal that is ferrous and has 3 other elements plus carbon
  E) a metal that does not have iron in it

Proportion Correct: June .273; September .636

40. What percentage of 4140 steel is carbon?
* A) .4
  B) 1.4
  C) 4
  D) 4.1
  E) 40

Proportion Correct: June .500; September .318

41. A national pipe thread has a taper in one foot of ...
  A) 1/8"
  B) 1/4"
  C) 3/8"
  D) 1/2"
* E) 3/4"

Proportion Correct: June .318; September .273

42. In which way is extra-heavy wall pipe similar or different from standard pipe?
  A) the inside diameter is the same as standard wall pipe
  B) the additional metal is added on the outside so the hole size remains the same as standard pipe
  C) it is larger on the O.D. and smaller on the I.D. than standard wall pipe
* D) the outside diameter is the same as standard pipe
  E) the wall thickness is the same as standard pipe, but the kind of steel used is much heavier

Proportion Correct: June .455; September .500

43. An important advantage of several pipe sizes having the same pitch (number of threads per inch), is ...
    A) none of the following are correct
    B) all of the following are correct
    C) that one coupling will join different pipe sizes
*   D) that with certain threading equipment, the same dies can be used for several pipe sizes
    E) that one tap will cut several different pipe threads

Proportion Correct: June .545; September .545

44. What is it about a 3/4" tap that is actually 3/4"?
    A 3/4" tap ...
    A) has a minor diameter that is 3/4"
    B) has a pitch diameter that is 3/4"
*   C) has a major diameter that is 3/4"
    D) will require a tap drill that will drill a 3/4" hole
    E) has a shank that is 3/4" in diameter

Proportion Correct: June .227; September .227

45. The angle between the sides of the American National Thread as well as the Unified National Thread is ...
    A) 29^o
    B) 30^o
    C) 55^o
*   D) 60^o
    E) 70^o

Proportion Correct: June .545; September .273

46. The purpose of 'set' on a hacksaw blade is ...
    A) to strengthen the blade against sideways wobble
    B) to provide for different pitches on different blades
*   C) to provide clearance in the kerf for the blade
    D) to keep the blade from dulling
    E) to provide more room for metal cuttings to clear out of the kerf

Proportion Correct: June .318; September .273

47. Machinist's squares are **NOT** used to ...
    A) help scribe lines at 90° to edges
    B) check edges to see if they were filed "square"
    C) check inside corners
    D) check outside corners
* E) check for accurate sizes

Proportion Correct: June .591; September .773

48. The softest part of a file is ...
    A) the edge
    B) the body
    C) the point
* D) the tang
    E) the space between the end of the teeth and the tang

Proportion Correct: June .636; September .545

49. "Kerf" is ...
    A) a special type of hacksaw
    B) another name for 'set' on a hacksaw blade
    C) the chips that are made when you file
* D) the slot that is made when you saw
    E) the chips that are made when you saw

Proportion Correct: June .591; September .545

50. What kind of arc welding rod is a 6011 rod?
    A) fast fill rod
    C) fill freeze rod
    B) low hydrogen rod
* D) fast freeze rod
    E) low hydrogen, fast fill rod

Proportion Correct: June .727; September .636

51. Arc blow can be reduced by ...
    A) increasing the amperage but not the voltage
    B) using a different kind of welding rod
    C) keeping the metal from getting too hot
    D) using a low hydrogen rod
*   E) reducing the amperage

Proportion Correct: June .864; September .636

52. When the arc welding rod is said to be 1/8", it really means that ...
    A) the build-up of the normal bead for that rod is 1/8" high
*   B) the diameter of the bare end is 1/8"
    C) the diameter on the main part (the coated portion) is 1/8"
    D) the bead width with correct amperage setting is, 1/8"
    E) as manufactured, the rod with coating, is 1/8" but it shrinks later

Proportion Correct: June .727; September .773

53. Why are arc weld craters sometimes kept some distance in from the edge of the metal?
*   A) B, C, and D, are all good reasons
    B) to prevent a crack from starting at the crater
    C) so the bead will look better
    D) to avoid melt off at the metal's edge
    E) none of the above are reasons

Proportion Correct: June .591; September .500

54. 6011 welding rod would indicate a tensile (pulling) strength per square inch of ...
    A) 11,000 lbs. (5,000 kg)
    B) 6,011 lbs. (2,700 kg)
*   C) 60,000 lbs. (27,000 kg.)
    D) 11 tons (10,000 kg)
    E) none of (A) to (D)

Proportion Correct: June .955; September .818

55. An important purpose of coating on the electrode is ...
    A) to form a shield of gases around the welding arc to keep out nitrogen
    B) to act as a conductor to help the current travel from the electrode holder to the job being welded
    C) to keep the rod from corroding
* D) to act as an insulation to prevent arcing on the sides of the electrode
    E) none of (A) to (D)

Proportion Correct: June .273; September .227

56. The approximate amperage setting for 1/8" 6011 welding rod would be ...
    A) 60
* B) 110
    C) 160
    D) 210
    E) 250

Proportion Correct: June .636; September .636

57. A welder with a 50% duty cycle and a maximum amperage output of 200 amps is designed to ...
    A) weld continuously at 200 amps
    B) weld at 200 amps in every other 20 minute period
* C) weld at 100 amps continuously
    D) weld at 100 amps 50% of the time
    E) weld at 400 amps one quarter of the time

Proportion Correct: June .591; September .455

58. Which statement best describes an A.C. - D.C. welder?
    A) usually used in 'field' work
    B) runs off a gas or diesel motor
* C) uses a rectifier
    D) the cheapest kind of welder
    E) all of the above are correct

Proportion Correct: June .545; September .455

59. An advantage of a D.C. welder is that it ...
    A) is preferred for fast fill rods
    B) is inexpensive to buy
    C) can be plugged into regular house electrical current
*   D) is best for out of position welding
    E) has no problem with arc blow

Proportion Correct: June .636; September .364

60. The cylinder valve of an oxygen tank should be opened very slowly because ...
    A) rapid opening of the cylinder valve causes a heat build up in the regulator, which combined with the oxygen, could cause an explosion of any organic dust that is in the regulator.
*   B) rapid opening of the valve causes the regulator to be hit with a shock pressure, that is far higher than what is normally in a full cylinder. This shock could rupture the regulator.
    C) it doesn't matter how slowly you open the tank valve as long as you can see the holes in the regulator screws
    D) rapid opening of the tank valve puts extra stress on the rubber diaphragm in the regulator resulting in a shortened service life
    E) none of the above are correct

Proportion Correct: June .773; September .727

61. Any oxy-acetylene regulator does all these things EXCEPT ...
*   A) regulate the pressure in the cylinders
    B) decrease the pressure from the cylinder to the hose
    C) keep the gas in the hoses at a desired pressure
    D) act as a valve to allow gases into the line
    E) serve as a safety device in keeping line pressures safe

Proportion Correct: June .455; September .591

62. Oxygen should never be used as a substitute for compressed air because ...
    A) of none of the following reasons
*   B) of all of the following reasons
    C) cloth or hair or oil, plus oxygen creates an extreme fire hazard, when oxygen is used to blow dust off one's self or one's clothing
    D) no gas over 15 PSI should ever be direct at or near flesh
    E) some equipment that is normally operated with compressed air would explode if operated on oxygen

Proportion Correct: June .591; September .455

63. In oxy-acetylene cutting, it is necessary to do all of these things EXCEPT...
    A) all of the following
    B) heat an edge of the steel to cherry red
    C) have the oxygen tank valve fully open
* D) have at least 20 P.S.I. of acetylene
    E) have the oxygen torch body valve fully open

Proportion Correct: June .818; September .773

64. The procedure for adjusting a neutral oxy-acet flame is ...
* A) begin with an acetylene flame and then slowly increase the oxygen
    B) begin with an oxidizing flame and then increase the acetylene until the acetylene feather just begins to appear
    C) begin with an acetylene flame and then open the oxygen until you hear quite a loud hiss
    D) open the acetylene valve one quarter of a turn and open the oxygen one whole turn
    E) open the oxygen valve until the acetylene feather is about one inch long

Proportion Correct: June .545; September .727