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ABSTRACT

The main purpose of the Air Force project was to develop a universal model to evaluate usage of basic electronic principles training. The criterion used by the model to evaluate electronic theory training is a determination of the usefulness of the training vis-a-vis the performance of assigned tasks in the various electronic career fields. Data collection is through a survey booklet, called the Electronic Principles Inventory, which is completed by practitioners in the field. The inventory is general in nature and can be administered to anyone who works with electronics, regardless of the level of involvement. The data can be analyzed using the Comprehensive Occupational Data Analysis Programs (CODAP). Significant results were found between and within electronic specialties. The results presented in the report would be useful to managers in the areas of training, personnel classification, and testing. (Author/EA)

A UNIVERSAL MODEL FOR EVALUATING BASIC ELECTRONIC COURSES IN TERMS OF FIELD UTILIZATION OF TRAINING

USAF OCCUPATIONAL MEASUREMENT CENTER

LACKLAND AFB, TEXAS

FOREWORD

The initial impetus for the project came from the Deputy Chief of Staff, Technical Training, Air Training Command. The work was conducted under the general supervision of Dr. Walter E. Driskill, Chief, Occupational Survey Branch, USAF Occupational Measurement Center, Lackland Air Force Base, Texas. Mr. Hendrick W. Ruck contributed significantly to the development of the instrument used in the project. Lieutenant Karl A. Hickerson was responsible for developing techniques for computer analysis and for subsequent studies related to the project.

The results presented in this report are not definitive and should be reviewed only as examples of the potential of the instrument.

Thomas J. O'Connor, Major USAF
Project Director

Introduction

In support of our primary mission, we train thousands of people. Some of the most expensive training is in the field of electronics. The Air Force alone has about 63,000 personnel involved directly in the electronic fields and the cost of their training runs into the hundreds of millions of dollars. The Air Training Command estimates that Air Force electronic training costs about a half million dollars per day.

Until now, there has not been any reliable method of identifying precisely the amount of electronic theory needed to perform various jobs. As a result, to be on the safe side, we tended to overtrain our personnel. The main purpose of this project is to develop a universal model to evaluate usage of basic electronic principles training.

The criterion used by the model to evaluate electronic theory training is a determination of the usefulness of the training vis-a-vis the performance of assigned tasks in the various electronic career fields.

It is important to be able to identify in a very specific manner those portions of the electronics training which contribute most and least to the performance of tasks. The identification of the relative merit of various portions of electronics training has important implications for managers in the areas of training, personnel classification and testing.

The Electronic Principles Inventory

General Background

The model developed in this project is called the Electronic Principles Inventory (EPI). The EPI or survey is different from the usual task oriented survey in two major respects. First, the EPI asks two general questions: What do you do and what electronic knowledge do you use in performing your job? The usual task survey concentrates on only one question: What do you do? The second difference is that the EPI can be administered to anyone who works with electronics. That is, it is general in nature, unlike the usual survey, which is aimed at a single specialty within a career field.

The EPI is similar to the usual survey in that the data can be analyzed using the Comprehensive Occupational Data Analysis Programs (CODAP).

The EPI contains two sections. Section one has the usual background information, such as rank, command, job title, active military service time, etc. Section two contains the electronic type questions. The content for the questions was taken from the Keesler Air Force Base Basic Electronic Principles Course, 3AQR30020-1. This course is the first military electronics course taken by personnel in 17 specialties within the Air Force and has a documented length of 18 weeks. A few of the specialties skip some of the lessons or modules. The reason the Keesler course content was chosen to be the

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base for formulating electronic questions was because it appears to be one of the most extensive in terms of the depth and breadth of electronics material.

A typical job description of an electronic specialty may include a general terminology which uses such verbs as monitors, analyzes, identifies, installs, maintains, troubleshoots, repairs, modifies, aligns, inspects, calibrates, isolates, etc. Two questions may be asked. First, does the action verb mean the same thing for different specialties? Second, even if the action verb does mean the same thing in a general sense for different specialties, does each specialty use electronic knowledge on the same depth and breadth dimension? The EPI results are independent of how one would answer the above questions. That is, the EPI asks questions at such a basic level that the data will yield the kind of information one can use to make decisions without being affected by semantic and communication problems that have plagued previous attempts to deal with the complexity of electronics training.

Brief Description of the Model

In general, electronics courses start with the simple and continually build toward the complex. That is, basic components such as resistors, capacitors, etc. are introduced first and eventually they are combined to form such items as power supplies or motors. The following example illustrates how the EPI determines the utilization of electronic principles training.

The example is for motors only but a comparable section has been written for resistors, capacitors, diodes, transistors, etc. The section on motors starts by asking: Does your job involve any tasks dealing with either alternating current or direct current motors? If the individual answers no, he is routed to the next section of the EPI. If the response is yes, the EPI seeks to determine specifically what tasks the individual performs on motors. The format is as follows:

Do you perform any of the following tasks on motors?

1. inspect . . . . [__] YES [__] NO
2. troubleshoot down to component parts . [__] YES [__] NO
3. troubleshoot as far as checking wire connections but do not troubleshoot down to component parts . . . . . [__] YES [__] NO
4. clean or lubricate . . . . [__] YES [__] NO
5. operate . . . . [__] YES [__] NO
6. remove or replace complete motors . . . [__] YES [__] NO
7. remove or replace motor parts . . . . . [__] YES [__] NO
8. other (specify) . . . . [__] YES [__] NO

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From an examination of the pattern of responses to the above tasks, some obvious assumptions about the level of electronic knowledge needed to do different tasks can be made. That is, an individual who removes or replaces complete motors generally doesn't need to know as much about motors as an individual who troubleshoots down to component parts.

The EPI also seeks to determine if the individual performs tasks on specific motor parts such as the field coil, armature, rotor, brushes, slip rings, commutator or pole pieces. Subsequent questions ask whether the individual is involved in determining magnitudes and directions of torque and induced voltages in motors. The final set of questions on motors asks about the types of motors the individual works on (synchronous motor, induction motor, etc.).

The complete data on motors and all the other sections are analyzed to determine field utilization of the electronic principles training.

Administration of the Electronic Principles Inventory (EPI)

Initial Field Test

In order to assess the universality of the instrument, it was decided to administer the inventory to personnel in career fields requiring various amounts of electronic knowledge. Figure 1 gives the specialties in the communications-electronics systems, missile electronics maintenance, and avionics systems career fields which were sampled.

307X0	Telecommunications System Control
316X1L	Missile System Maintenance
324X0	Precision Measuring Equipment (PMEL)
326X0	Avionics Aerospace Ground Equipment (AGE)
328X3	Electronic Warfare System

Figure 1. The electronic specialties which were field tested.

Another variable addressed in selecting the sample for the initial field tests was Major Air Command. Airmen serving in the Strategic Air Command, Tactical Air Command, and Aerospace Defense Command were surveyed. These three commands represent the bulk of USAF airpower in the continental United States.

The EPI was administered to small groups of airmen (N=200) by project members at seven different locations throughout the United States. Average time needed to take the EPI was one and a half hours.

Full-scale Administration

Once the EPI has been reviewed and finalized it will be administered worldwide to all Electronic Warfare System personnel (AFSC 328X3) and all Telecommunications Control Systems personnel (AFSC 307X0) in the Air Force. Preliminary data from the initial field test indicate that significant results regarding training and personnel classification can be found for these specialties. It is expected that the worldwide administration will take place in December, with initial data being available in March 1976.

Results and Applications

Since the results presented here are based on a limited field study, the emphasis in this section will be on potential applications of the results of surveys using the Electronic Principles Inventory (EPI).

Electronic Principles data can impact meaningfully on several major functions which include technical training, personnel classification, and promotion testing.

Technical Training and Personnel Classification

Preliminary results indicate that personnel in different specialties use different amounts of electronic principles theory in performing their jobs. Figure 2 shows the average use of electronic principles theory, which is indicative of the probability of use by any one individual within a specialty. The range of average use is from 10% to 51%.

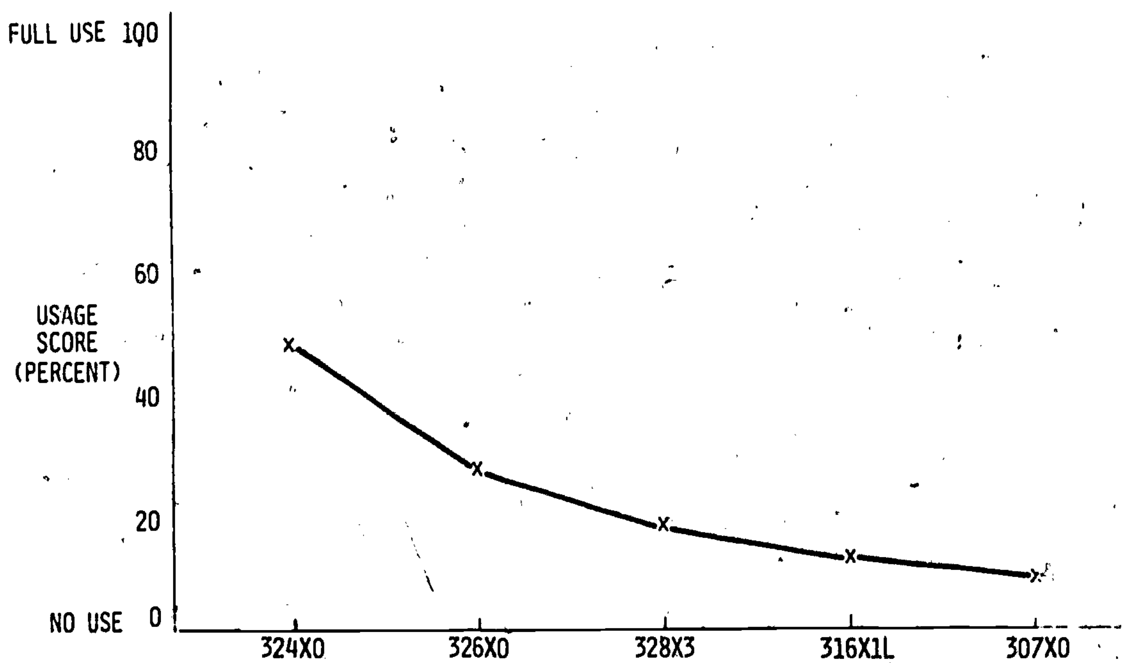

Figure 2. Average use of electronic theory by five specialties in the Air Force.

Training organizations, however, are more interested in the total use of electronic principles theory by all individuals in the specialty. The data shown in Figure 3 indicate a range of total usage between 14% and 84%.

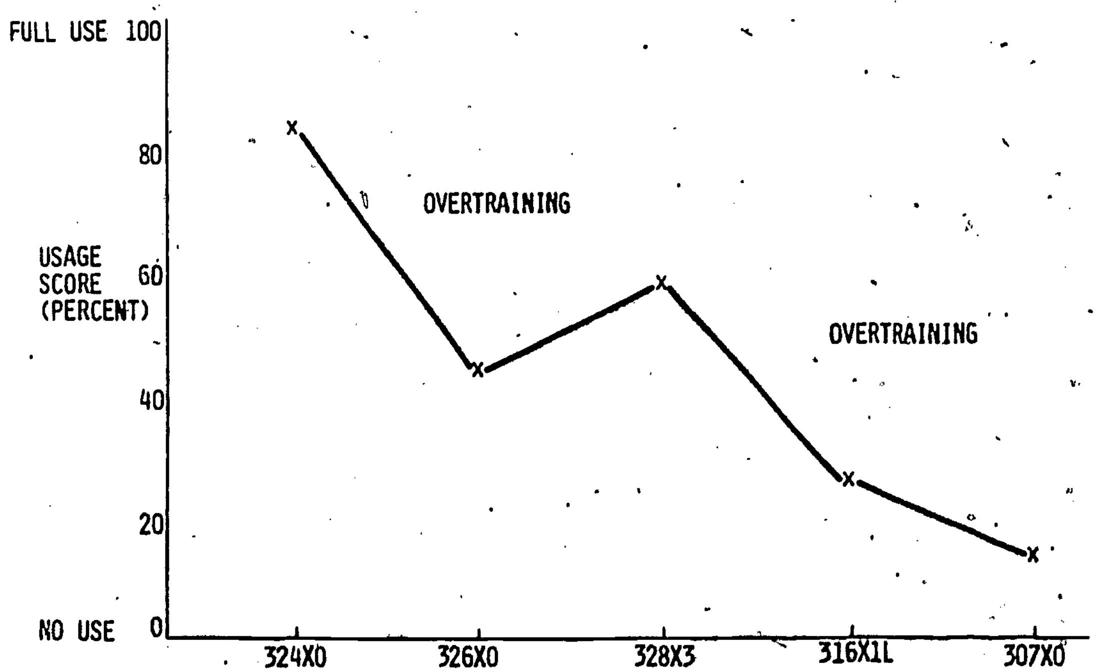

Figure 3. Total use of electronic theory by all individuals in five Air Force specialties.

The percent or area above the curve represents overtraining. That is, nobody in specialty 324X0 indicated a use for 16% of the electronic principles theory; 86% of the taught electronic principles theory is not used by specialty 307X0 personnel. Relating the data on the curve to the mental framework for analysis developed in Appendix A, one can see that the area below the curve represents the depth and breadth of electronic principles knowledge used by the specialties.

In support of the conclusion that nobody uses the theory above the curve, the specific information (16%) that specialty 324X0 does not use was identified. The group of 324X0 specialists that writes the Specialty Knowledge Test (SKT) was asked questions about this information. They indicated no use of, familiarity with, or relevance for such information in their job. Yet, one can go to some of the basic electronic courses and find that an individual cannot progress through the course unless he demonstrates his comprehension of such knowledge. Referring to the model developed in this project, it can be shown that much of this extraneous course information is presented at a depth below the level of practical use, that is, at the structure and process MICRO level (in Appendix A), which generally is of importance only to design engineers.

To further validate the conclusion that information above the curve represents overtraining, the extraneous information was compared with the course material of an electrical engineering department at the college level. The comparison itself was made by the faculty of the college. They concluded that: "Only about 5% of the extraneous information is taught here [at the institution]; the rest is physics theory."

The data also indicate that most of the knowledge is cumulative between specialties. Take, for example, the knowledge used on the job by 307X0 personnel and compare it with the knowledge used by 324X0. The 324X0 personnel use the same 14% of the knowledge which is used by the 307X0 personnel, and an additional 70%.

Figure 4 combines the two previous curves and gives an overview of the full impact of the data.

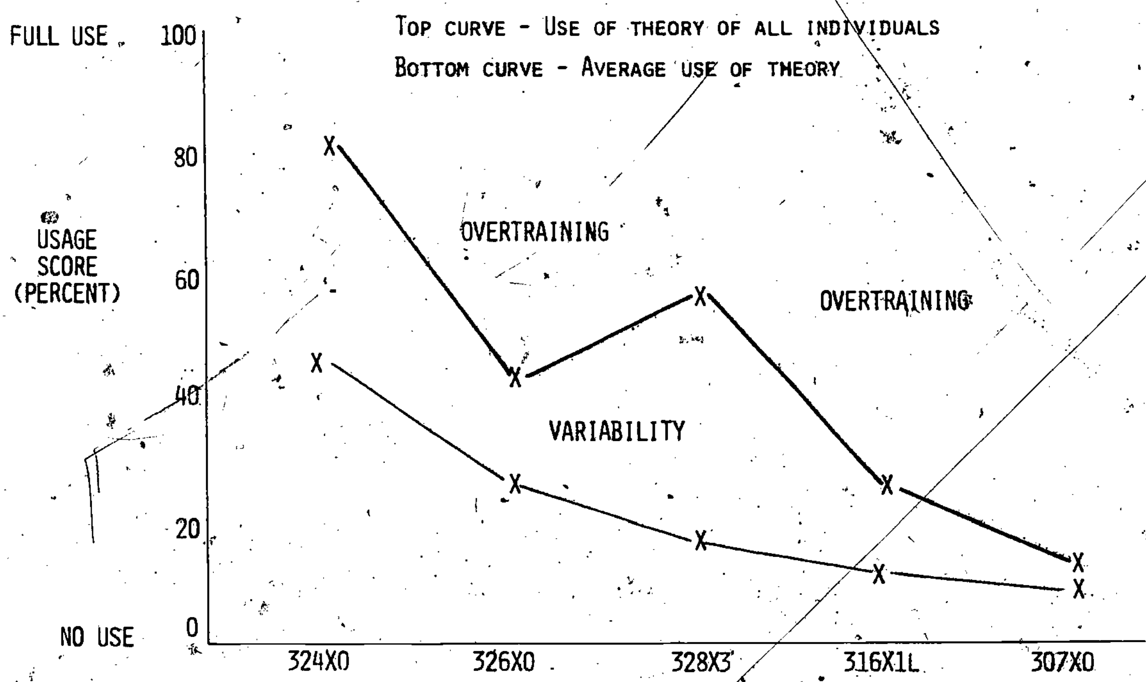

Figure 4. Total use and average use of electronic theory by five specialties in the Air Force.

The data can be divided into the following categories:

1. The percent or area <u>above</u> the top curve represents overtraining within each specialty.

2. The percent or area <u>below</u> the top curve represents the total usage made of electronic theory training within each specialty.

3. The percent or area between the curves represents the degree of variability of use of electronic training within each specialty. Variability for each specialty is determined by subtracting the appropriate value on the bottom curve from the value on the top curve. This value gives a difference or variability score whose utilization will be discussed shortly.

4. The percent or area below the bottom curve represents the average use made of electronic theory training within each specialty.

Table I presents the same data as the curves in Figure 4. One obvious use for this information is in formulating a hierarchy of specialties based on technical difficulty. Since there is a large amount of overlapping of the uses of electronics theory between specialties, the establishment of a hierarchy of specialties based on technical difficulty can provide managers with data to make decisions on determining the most equitable moves (forced or volunteer) between specialties. For example, when one specialty needs to be filled, the question arises: What other specialties are the closest in terms of use of electronic knowledge? Specifically, if vacancies in 326X0 existed, it would be more logical to move people into that specialty from 324X0 and 328X3 than from 307X0. If it became necessary to fill 326X0 slots with 307X0 personnel, a refresher basic electronic course would seem desirable. On the other hand, if vacancies existed in 307X0, any of the specialties listed above 307X0 could easily fill the slots after an equipment orientation.

Table 1

Percent of Average Use and Total Use of Electronic Principles Training by Five Air Force Specialties

AFSC[a]	Average use	Total use	Difference
324X0	50.65	83.96	33.31
326X0	31.18	43.98	12.80
328X3	20.18	57.68	37.50
316X1L	15.09	25.80	10.71
307X0	10.49	13.72	3.23

Note. According to Air Force Manual 39-1, all specialties listed require the same minimum electronics score (80) for entry into the specialty.

[a]Air Force Specialty Code

Another use for the data is in the determination of whether to combine or shredout various specialties. For example, a specialty with a high usage score and a high difference score is indicative of a specialty which uses a high level of electronic theory, and in which groups of individuals within the specialty use different portions of electronic theory. Based on this data, one would perhaps recommend a shredout of the specialty. The data can also be used to give managers an indication of the amount of cross-training needed by personnel within a given specialty. A low variability or difference score indicates that personnel in that specialty can be moved around easily. For example, for 307X0, the degree of variability within the specialty expressed as a difference score is 3.23. Compare this with 33.31, the difference score for 324X0. What this comparison means is that, based on the use of electronic knowledge, personnel in 307X0 are comparatively easily cross-trained within the specialty, whereas, personnel in 324X0 are not. This conclusion has been partially verified by interviewing 307X0 and 324X0 specialists.

This data could also be used as inputs to either of the following decision processes: (1) that which involves a reduction-in-force (RIF); (2) that which involves who will be allowed to reenlist (selective reenlistment). Other things being equal, it would make more sense to retain those people with a higher experience level in electronics. High usage scores are indicative of a career field with a high experience level in electronics.

Another application for the data shown in Table I relates to the initial placement of personnel in various specialties. Presently, all the listed specialties require the same minimum electronics score (80) for entry into the specialty. The hierarchy of specialties based on electronic difficulty gives program managers options such that they could place persons with higher electronic aptitudes in the more difficult electronic specialties. For example, the 324X0 (Precision Measuring Equipment) specialty could receive a larger proportion of persons with higher electronic scores. Since the 324X0 personnel perform the critical calibration tasks for most of the electronic equipment used by all Air Force specialties, the concept appears sound.

Impact on Interservice Electronic Training

The model could be used to initiate a feasibility study for determining the extent to which electronic specialties in each service overlap in their use of electronic theory. Based on this information, decisions could be made concerning joint training. If joint training is implemented, the model could be used to evaluate continually and update the training programs. For those military specialties whose training it is not advisable to combine, the model can, as a minimum, provide information on those portions of electronic theory which are most used, least used, and not used.

Specific Comments on Training

In general, electronic principles training is broken into a series of discrete modules, sections, or lesson plans. A trainee for a specific Air Force specialty may be required to pass any subset of these modules before being allowed to train on the equipment he will work with in the field. The EPI has been constructed in such a manner that its sections correspond with the modules. Thus, the data are immediately usable by the training units. Table 2 illustrates how one could determine which lessons or modules of training are required by field personnel to perform their jobs. The example is for AFSC 328X3 (Electronic Warfare Systems personnel); the last column of numbers shows the percent of each module which is actually used in the field by all 328X3. Further, the data can be broken down by command, as shown by the first and second columns, which compare Strategic Air Command (SAC) 328X3 personnel with Tactical Air Command (TAC) 328X3 personnel. The data could be broken down by any chosen variable, such as time in service, grade, etc.

Table 2

Percent of Theory Used by SAC and TAC Electronic Warfare Systems Personnel (328X3)

Subject	SAC 328X3	TAC 328X3	SAC AND TAC 328X3
D. C. and Voltage	44	44	44
Multimeter Uses	60	60	60
Meter Movements	75	75	75
Transformers	37	47	50
Relays	50	50	50
Microphones	0	40	40
Speakers	0	44	44
Motors	63	0	63
Generators	23	0	23

One can also compare usage of modules between specialties. Both specialties, 328X3 and 307X0 (Telecommunications System Control) take the same course with minor variations. The first column of numbers in Table 3 shows the percent of theory needed by 328X3; the second column shows the percent of theory needed by 307X0; the third column shows the combined need for theory by 307X0 and 328X3. The third column of numbers gives an indication of the overlap of theory, and thus is useful in making decisions about combining basic electronic courses. The data indicate that the 307X0 personnel are not using any of the listed theory portions of their basic electronic course beyond speakers. Although this example is from limited data collection, the results are corroborated from the occupational survey done on AFSC 307X0 (AFPT 90-307-081) which shows an extremely limited basic technical role for 307X0 personnel. In addition to the obvious conclusion that 307X0 personnel are overtrained, other inferences can be made. First, if the present course for 307X0 personnel were reduced in scope, it is probable that fewer students would be eliminated due to academics. Second, shorter courses mean quicker utilization of personnel in the field and reduced training costs. Third, persons, such as those taking the longer course required for 324X0 and who are eliminated for academic reasons, could be considered for the 307X0 specialty, or other less demanding (in the electronic sense) specialties. Thus, the time and money already invested in the person could be salvaged.

Table 3

Percent of Theory Used by

328X3 and 307X0 Personnel

Subject	328X3	307X0	307X0 and 328X3
D. C. and Voltage	44	33	44
Multimeter Uses	60	60	60
Meter Movements	75	83	83
Transformers	50	16	53
Relays	50	0	50
Microphones	40	13	40
Speakers	44	31	50
Motors	63	0	63
Generators	23	0	23
Diodes	45	0	45
Transistors	59	0	59
Transistor Amplifiers	81	0	81
Electron Tubes	38	0	38
Power Supplies	78	0	78
Saturable Reactors and Magnetic Amplifiers	6	0	6
Synchro-Servo Systems	0	0	0
Transmission Lines	56	0	56

Table 3 (Continued)

Subject	328X3	307X0	307X0 and 328X3
Antennas	65	0	65
AM Systems	91	0	91
FM Systems	91	0	91
Single Sideband Systems	90	0	90

At a more refined level of data reduction, the EPI gives a hierarchy of percent responding yes to specific EPI statements. Figure 5 shows those items in the EPI to which 50% to 60% of the 328X3 sample responded yes. The items shown reflect the actual field use of the material taught, or that which should be taught, in the basic electronic course.

DO YOU WORK WITH DIODES ON YOUR PRESENT JOB?

DO YOU REFER TO OR NEED TO HAVE A KNOWLEDGE OF:

HOW TO REPLACE DIODES ON A CIRCUIT BOARD?
HOW TO REPLACE DIODES ON A CHASSIS?

DO YOU REFER TO OR USE:

TRANSISTOR SCHEMATIC SYMBOLS?
TRANSISTOR SUBSTITUTION INFORMATION?

DO YOU WORK WITH TRANSISTOR AMPLIFIERS ON YOUR PRESENT JOB?

FIGURE 5. REPRESENTATIVE ITEMS TO WHICH 50% TO 60% OF THE ELECTRONIC WARFARE SYSTEMS PERSONNEL RESPONDED YES.

On the other hand, Figure 6 shows those items which are taught in the basic course and which nobody in the field uses.

DO YOU REFER TO:

NUMBER OF ELECTRONS IN A PARTICULAR SHELL OR ORBIT?
ATOMIC NUMBER?

CONDUCTION BAND IN SEMICONDUCTOR MATERIALS?

ACCEPTOR IMPURITY IN SEMICONDUCTORS?

DO YOU USE OR REFER TO THE TRANSISTOR GAIN GAMMA?

DO YOU CALCULATE THE FOLLOWING TRANSISTOR GAINS:

ALPHA?
GAMMA?

DO YOU COMPUTE THE STATIC OPERATING POINT (Q) OF A TRANSISTOR AT DIFFERENT TEMPERATURES?

DO YOU USE OR REFER TO THE ELECTRON TUBE PARAMETER CALLED AC PLATE RESISTANCE?

DO YOU CALCULATE AC PLATE RESISTANCE?

FIGURE 6. REPRESENTATIVE ITEMS IN THE EPI TO WHICH NOBODY IN THE SAMPLE OF 328X3 RESPONDED YES.

At present, we have little or no information about the utilization of basic electronic theory for individuals or groups over time within any given specialty. The curves shown in Figure 7 demonstrate another application of the EPI data. The curves represent hypothetical usage

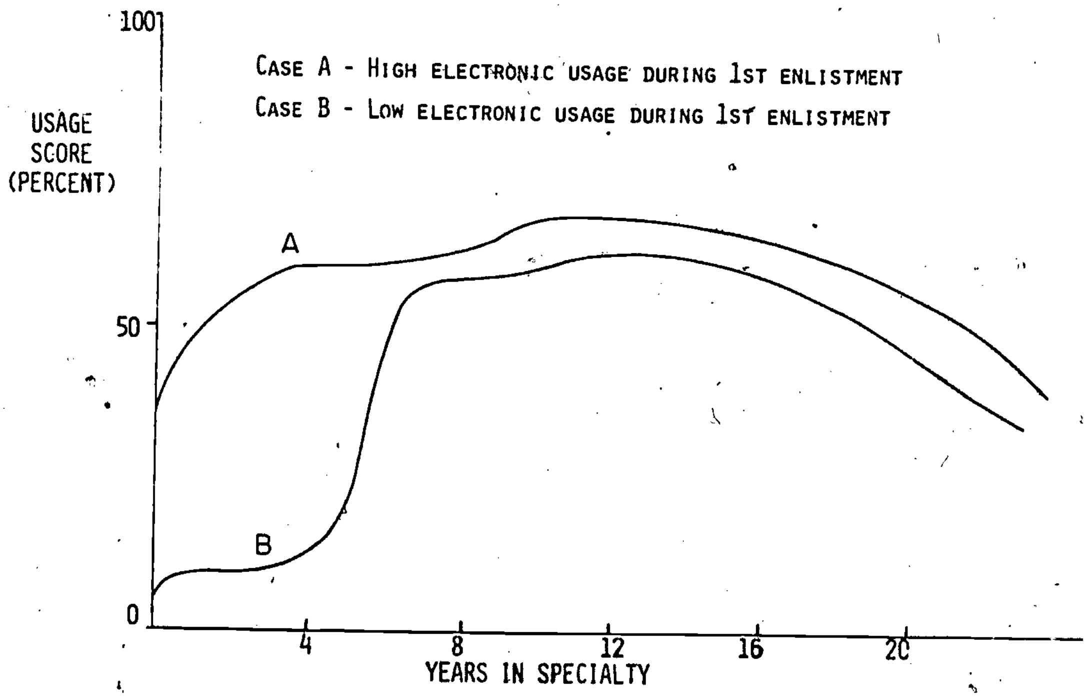

Figure 7. Two hypothetical usage curves for a given specialty over a 20 year period.

for two possible cases. For Case A, use of electronic theory is high in the first four years; thus implying the need for a rather extensive basic electronic course immediately after enlistment. Case B illustrates a low initial usage for the first few years, with accelerated usage after the four year point. Since many military personnel depart the service after their initial enlistment, it might be worthwhile, for Case B, to delay extensive theory training until after the individual reenlists.

Related to training, another use for the EPI data is in the determination of what should be taught in a new course. In the hypothetical case of a new electronics specialty, a manager could have the writers of the technical and maintenance manuals fill out the EPI. The resulting data could be used to form the core for the new course.

The data from the EPI can also be used as a basis for interaction between the training managers and the using agencies. It is not uncommon for the using agencies to request that the training people reevaluate their basic electronic courses. Such requests may state: "Give your students more theory" or conversely, "Give your students less theory." Specifically what is meant by such general words as theory, basics, principles or fundamentals is not usually clearly defined. Even less clear is the task of identifying which portion of the theory course is to be taught more, or which portion is to be taught less. The model developed in this project, when applied by the training managers, is able to identify in a very specific manner the most field-relevant and the least field-relevant information in the training course. Likewise, the results from the EPI will enable the using agencies to levy more realistic training requirements on the training programs.

Promotion Testing

Specialty Knowledge Tests (SKTs) are used in the Air Force as one factor in the airmen promotion system. These tests traditionally are composed of basic electronic theory questions as well as specific equipment questions for each of the electronic specialties. At present, there is no hard data on which portions of the basic electronic theory apply most to a given specialty. EPI data can provide guidelines for establishing specific sets of knowledge items which may be used for knowledge tests for given specialties, and thus support or increase present test validity. Within the same specialty, the EPI is able to determine which basic electronic questions are the most equitable to ask. For example, refer back to Table 2, which compares SAC and TAC electronic warfare specialists (328X3). From Table 2 it can be seen that SAC 328X3 personnel do not work with microphones and speakers, while TAC personnel do not work with motors and generators. Each group would be at a disadvantage if asked questions about items they do not work with. In addition to the selection of the most equitable test items for a specialty, the EPI also gives the testing people an indication of the risks involved in the testing procedure by not having certain commands represented when the tests are being constructed.

One of the implications of establishing sets of theory questions which are job relevant for specialties would be to have a panel of electronic theory experts develop an item bank of electronic theory test items for all electronics specialties. Specialists could then select items from the item bank for their own specialty, thus reducing their workload, since they would only have to develop equipment test items. The bank would be of such a size that any possible compromises of a test could be handled by switching to a new set of basic electronic principles questions.

Since the SKTs are made by groups of personnel on temporary duty status, a reduced workload can be interpreted in terms of money saved.

Conclusion

The Electronic Principles Inventory (EPI) represents a major contribution in the identification of the type of electronic training needed to perform any job. It is general in nature, and thus can be administered to anyone who works with electronics, regardless of the level of involvement (maintenance, operations, training, etc.).

The data from the EPI can be used:

1. By training organizations to evaluate existing programs and to make decisions about the organization of new programs.

2. By managers interested in the feasibility of combining training programs.

3. By field organizations to evaluate the utilization of training and to determine what is needed in terms of deficiencies.

4. By people who work on personnel classification systems to determine optimum utilization of manpower between and within specialties.

5. By testing personnel to determine which portions of the electronic theory relate to actual utilization.

APPENDIX A

Theoretical Foundations of the Electronics Principles Inventory

In order to evaluate an already existing basic electronics course, or to establish a new course, one is faced with questions involving the "what" and "how much" of electronics. In order to discuss these things, the hypothetical constructs of depth, breadth, structure, process and product have been devised. Oftentimes, it is not a matter of teaching or of not teaching something; it is a matter of the degree or the level at which something should be taught.

The Depth Dimension of Electronics

Perhaps the best way to talk about the depth dimension of electronics is by way of illustration. Resistors will be used as the instrument of discussion, since most persons have some idea of what resistors are and do. In dealing with resistors the following questions demonstrate the levels of the depth dimension.

1. Should the person working with resistors have the general knowledge that most resistors show a decrease in efficiency with increasing heat or;

2. Should the person working with resistors have the specific knowledge that the resistor he is working with has a 10% loss of efficiency for 5% increase in temperature within a specified operating range or;

3. Should the person working with resistors have a knowledge of how to compute or derive the equation upon which the information in two (2) above was based?

The issue is: At what level of electronics should the person be concerned with? That is, what is the level of knowledge used in the monitoring, troubleshooting, etc., of electronics? Question one deals with the MACRO level of the depth dimension and questions two and three deal with the MICRO level of the depth dimension.

The Breadth Dimension of Electronics

There is a finite number of components, subassemblies, and assemblies in electronics. That is, we have components such as resistors, capacitors inductors, diodes, transistors, tubes, etc. We have subassemblies which use resistors, capacitors, inductors, diodes, transistors, tubes, etc., in various combination of parallel and series circuit elements. Then we have the complete assembly, such as a power supply or oscillator, which usually includes a number of subassemblies. The fewer the number of components, subassemblies and assemblies one has to deal with, the smaller his breadth dimension of electronics.

The Structure, Product, and Process of Electronics

The depth and breadth dimensions of electronics provide a partial framework within which it is possible to organize ideas about electronics. To complete the framework, the structure, product and process of electronics will be discussed.

All electronic items have physical characteristics (structure) such as size, color, type of material, etc. Likewise, electronic items have input and output products. For example, a signal goes into an amplifier at a specified level of input and comes out at a higher level of output. In general, electronic personnel are interested in determining if the input, output, or both are within acceptable levels. This is true for monitoring, analyzing, troubleshooting, repairing, aligning, calibrating, isolating, etc. Herein lies the central question: What electronic knowledge is used in performing those functions (monitoring, analyzing, etc.)?

On the other hand, the process of electronics has to do with what is happening to the structure from time of input product until time of output product. Figure A demonstrates the relationship between structure, product and process.

Figure A shows a transistor amplifier whose structure consists of the capacitor C_G, the resistors R_D and R_L and the transistor Q_1. The current (input product) is 50 microamperes (μA) and the amplified output product is 2 milliamperes (mA). The process which is occurring inside the transistor is shown in the graph at the lower right of the figure. The information on this figure will be used shortly to demonstrate some major points.

Synthesis

The depth, breadth, structure, product and process of electronics will now be combined in such a manner as to provide a useful framework for organizing or evaluating basic electronics training.

The monitoring, analyzing, troubleshooting, or whatever else is done in electronics, represents some aspect of checking a given input product, output product, or both. The following questions provide the basic underpinnings for the synthesis.

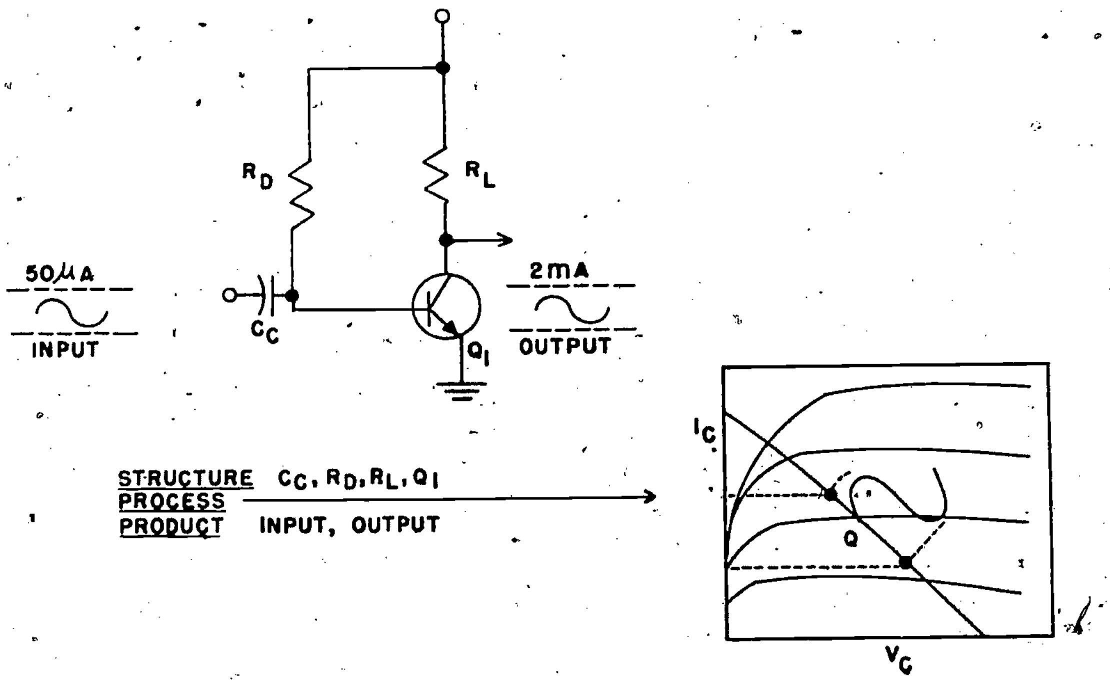

Figure A. A transistor amplifier circuit.

1. During the monitoring, analyzing, troubleshooting, etc., of electronic components, how much depth information about the structure of components is used?

2. During the monitoring, analyzing, troubleshooting, etc., of electronic components, how much depth information about the process going on inside the components is used?

3. During the monitoring, analyzing, troubleshooting, etc., of electronic subassemblies, how much depth information about the structure of the subassemblies is used?

4. During the monitoring, analyzing, troubleshooting, etc., of electronic subassemblies, how much depth information about the process going on inside the subassemblies is used?

5. During the monitoring, analyzing, troubleshooting, etc., of electronic assemblies, how much depth information about the structure of the assemblies is used?

6. During the monitoring, analyzing, troubleshooting, etc., of electronic assemblies, how much depth information about the process going on inside the assemblies is used?

The six questions listed above seem repetitive and indeed they are. However, since they form the core of the EPI framework, they are well worth emphasizing.

It would appear logical that a person who monitors meters would answer the six questions generated above in a different fashion from a person who repairs meters, or from a person who uses meters as an analytical tool for troubleshooting down to component parts. If in fact, the pattern of answers is quite different for the persons performing the three functions (monitoring, repairing, or using to troubleshoot to component parts), then is it not logical to ask if their training in basic electronics should be on a different scale? The initial findings of this project are that the patterns of responses are indeed widely varied between career fields and specialties; yet, the training in many cases is similar. Another illustration of the same point could be made by giving the identical set of electronic-use questions to two persons employed by a television repair shop. In this hypothetical example, let one person be responsible for picking up the television set or for removing major components, such as the power supply. Let the second person be responsible for repairing the faulty components in the shop. Should both be required to receive extensive training in electronic principles? This example has in fact real counterparts in some of our military electronic fields and in the electronic principles training associated with those fields. The problem has been in being able to identify the "what" and "how much" of electronic training actually used by each electronic specialty. The EPI is able to identify the "what" and the "how much" in a precise manner for each specialty.

An Example Using the Synthesis

If one wants to write statements which can be used to analyze and evaluate an already existing basic electronic training program, or if one wants to initiate a new training program, the same approach can be employed. Figure A will be used again to illustrate how the Synthesis works. Take the case where there should be an output but there isn't one. The individual would be troubleshooting for the cause.

The components are C_C, R_D, R_L, and Q_1, which are the capacitor, the resistors and the transistor respectively. The first set of questions (refer to question 1 under Synthesis) is concerned with how much one has to know about the structure of the components in order to troubleshoot. Certainly, for troubleshooting one must be able to distinguish between C_C, R_D, R_L and Q_1 based on physical characteristics such as size, color, shape, etc., (the MACRO level). Does one need to know things about the MICRO level of the structure of the components, such as the type of materials the components are constructed from? At a still lower MICRO level, does one need to know about the atomic structure of the material (number of neutrons, protons, electrons, etc.)?

The next set of questions (refer to question 2 under Synthesis) has to do with how much one has to know about the process going on inside the components in order to troubleshoot. For troubleshooting, one should know that the transistor Q_1 acts as a variable resistor and that it has a forward and reverse bias (the MACRO level). Does one need to know things about the MICRO level of the process of the transistor, such as the movement of minority or majority carriers? At a still lower MICRO level, does one need to know about energy level diagrams which describe barrier height and width? Using this second set of questions, the same statements could be applied to the capacitor and to the resistors.

As has been done above, a set of questions could be generated from questions 3, 4, 5 and 6 listed under Synthesis.

All the questions or statements used in this example have been applied to the case of someone troubleshooting a transistor amplifier. Even for this case of someone actually touching the components (assuming troubleshooting involves "hands on" maintenance), many of the MICRO statements developed for structure and process do not apply. How much less applicability do these questions and statements have for someone who does not touch components, such as for a person who monitors or operates electronic equipment?

Conclusion

The Electronic Principles Inventory developed in this project analyzed the electronic principles course content using the Synthesis described above as a mental framework for developing a set of approximately 600 statements which would determine actual use of electronic principles in the field.