ESTIMATING CURRICULA DEVELOPMENT COSTS: A MODEL BASED UPON THE COMPLEXITY OF THE LEARNING TASKS

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ABSTRACT

In every curriculum development effort, whether it is done in-house or under contract, it is necessary to estimate the funds which will be required for completion of the effort. Too often, this cost estimation is calculated using nonsystematic methods. Usually, the estimator's individual intuition and past experience are the only bases for this crucial work. The final curriculum often suffers when poor initial cost estimation leads to either deficient resources for the development effort or wasted funds because of over-estimation. This paper details a method for systematically estimating curriculum development costs. The proposed method breaks the projected development effort down into the tasks called for by the Instructional Systems Development (ISD) model (i.e., objective development, instructional sequencing, etc.). The work effort required to perform these ISD tasks is then examined in light of the total length of the course and the projected hourly costs for development time. Using this method, a curriculum cost estimate is developed which is based upon the learning complexity of the tasks to be trained. The tasks to be trained can be divided into five categories (Gagne, 1979): verbal information, intellectual skills, motor skills, attitudes, and cognitive strategies.

INTRODUCTION

Presently, even the most modest curriculum development effort requires a considerable amount of funding. However, despite this need for the proficient estimation and management of funds, many training professionals find themselves somewhat lost when they encounter cost estimation. Andrews and Thompson (1982) presented a formative model for curriculum development cost estimation. The present paper extends and refines that model. The sections on the learning domains and their effect on the model are new for this paper.

A prime mission of the military training community is the development of "training systems". A major portion of the training system is the curriculum. Virtually every training system in the military has a curriculum. When a new training device is introduced, the curriculum must be revised if it is already in existence, or it must be developed from scratch if the device is for a new course. Whether it is initial curricula development or curricula revision, some resources (e.g., funds, people, time, etc.) are necessary.

The development/revision effort is usually accomplished in one of four ways: 1) a government analyst-designer performs the effort in conjunction with the instructors at the formal school; 2) the school develops the curricula with its own resources; 3) a regional instructional development center performs the effort; or 4) the effort is performed under contract. For each method, resources must be planned for in as accurate a manner as possible. If the resource estimate is too low, the curricula will ultimately suffer. If the estimate is too high, the result will be waste and perhaps a loss of credibility for those analysts who made the estimates.

<u>Assumptions</u>: Before presenting the cost estimation model, six assumptions must be stated:

1. There are many different definitions of curriculum (e.g., Eisner, 1978; Kaufman and English, 1978; and Gagne and Briggs, 1979). One systematic approach to curriculum development, which has gained widespread use in the military training community, is known as the Interservice Procedures for Instructional System Development (IPISD) (Branson, et al., 1976). Within the model's five main phases (Analysis, Design, Development, Implement and Control) are encompassed most of the processes and products required in other system models. Throughout this paper, when curricula development efforts and costs are discussed, it will be assumed that the curricula are developed using the methodology set forth in the IPISD guidelines. These steps are listed later in the paper.

2. The term "cost" has many economic interpretations (e.g., Fisher, 1970). It is assumed in this paper that the term refers to those costs involved in the acquisition of resources for which the agency or activity must make explicit monetary payments or budget allocations. It is the combination of direct labor and overhead. This is Swope's (1976) definition of explicit cost.

3. It is assumed that the expertise of the curriculum developer is at the journeyman level. Obviously, people will vary in efficiency and effectiveness; however, the model does not presently account for this variation. Future versions of the model will attempt to address this variation in talent.

4. It is assumed that the instructional delivery system is group-paced, platform instruction.

5. In accordance with the IPISD model, it is assumed that the costs estimated are for occupational training, primarily in the military environment.

6. A final key and fundamental assumption of this model is that learning complexity effects the cost of instructional material development. For example, the conditions necessary for motor skill learning are different than verbal information learning. Consequently, the instructional techniques and associated costs of developing the respective curricula will be different.

Before we discuss how learning complexity can be determined and the effect that it has on the model, it is first necessary to examine the concept of learning categories or domains (intellectual skills, cognitive strategies, verbal information, attitudes, motor skills). The following section defines and gives examples of these domains. However, if the readers are familiar with the generic types of learning they may choose to move to the Cost Estimation Model section of this paper for the model description.

Domains of Learning

One of the tenants of the IPISD model is that instructional design should be based on the knowledge of the conditions of human learning. Gagne and Briggs (1974) maintain that human learning can be divided into five categories or domains and that all instructional objectives belong to one of these domains. Since the conditions that promote the learning of each domain are different, it is essential to consider these conditions in the design of the instruction. It is equally essential to consider their impact when making cost estimates.

These domains are not hierarchically related. That is, one domain is not considered *more or less difficult to learn than are other* domains. The domain differs in that the conditions of learning that must be present for learning to take place are not the same. Also, it is more difficult to construct curricula for the intellectual skills domain than it is for the other domains.

Intellectual Skills The first domain "makes it possible for an individual to respond to his environment through symbols. Language, numbers, and other kinds of symbols represent the actual objects of the person's environment" (Gagne and Briggs, 1974, p.36). The intellectual skill domain encompasses the concepts, rules, and problem solving techniques which we use to make sense of the world. Military examples of intellectual skills are: math skills for aircraft engine troubleshooting, interpretive skills for reading a contour map, and solving tactical problems using existing rules. Merely reciting rote definitions of mathematical rules or tactical doctrine are not examples of intellectual skills. A deeper conceptual understanding is necessary if intellectual skills are to be learned. Discriminations, concepts, rules and problem solving strategies are related in a sequential manner known as a learning hierarchy, which is nothing more or less than a chart of the subordinate skills related to some particular complex skill that is to be learned.

Cognitive Strategies The second domain is a very special type of intellectual skill. "This variety of capability is given a different name because, although it may be categorized as an intellectual skill, it has some highly distinctive characteristics. Most important of these characteristics is that a cognitive strategy is an internally organized skill which governs the learner's own behavior. The term cognitive strategies applies rather generally to various skills that are used by the learner to manage the processes of attending, learning, remembering and thinking" (Gagne and Briggs, 1974, p.47). Military examples of cognitive strategy use are the development of novel tactical problem solutions and novel methods for troubleshooting aircraft engines.

Verbal Information The third domain consists of all of the rote pieces of knowledge which a trainee memorizes. Labels, names, facts and various bodies of organized information (e.g., periods of military history; categories of anti-submarine warfare terminology; mine warfare terminology). Military examples of verbal information which can be memorized are: various types of equipment operating procedures, radio frequencies, and weapon characteristics. Recently, schools, both military and public, have been critized for concentrating too much on the teaching of verbal information to the exclusion of intellectual skills. While it is very important that intellectual skills in all their variety be well learned by trainees, verbal information, which is important in the learning of intellectual skills, should not be neglected.

Attitude Learning The fourth domain deals with *"complex states of the human organism which* affect his behavior towards, people, things and events." (Gagne and Briggs, 1974, p.61). Attitudes have both affective and cognitive components which makes this type of learning fairly complex. "The learning of attitudes and the means of bringing about change in attitudes are rather complex matters, concerning which much is yet to be discovered. Certainly the methods of instruction to be employed in establishing desired attitudes differ considerably from those applicable to the learning of intellectual skills and information." (Gagne and Briggs, 1974, p.63). Examples of attitudes to be learned in the military are: safety awareness, discipline, and respect for the enemy force.

Motor Skills Motor skills are learned capabilities that underlie performances whose outcomes are reflected in the rapidity, accuracy, force, smoothness or bodily movement. There are many military examples: adjusting a potentiometer, firing a rifle, and piloting an airplane are all examples of motorskills.

THE COST ESTIMATION MODEL

The discussion of the model consists of four parts. First, the definition and calculation of "work effort points" is given. Second, the conversion of "work effort points" into cost estimates is described. Third, the impact of various types of learning on the curriculum cost estimation process is discussed. Fourth, dollar per hour cost estimates are given and discussed.

Before proceeding with the description of the model it is imperative that we make a few parenthetical comments regarding the nature of the model and the estimation process. No one likes to be imprecise in their work, especially where money and fiscal responsibility are at issue. The model being presented is far from precise, but we have endeavored to bring some level of measurement to the process, with the goal of making most decisions at the ordinal level.

The cost estimation process is made on two dimensions or variables of the curriculum. First is the length or scope of the curriculum, and second is the learning complexity of the curriculum. The procedures for estimating cost within the model can be grouped under these two variables. The following paragraph gives an overview of the model which is then discussed in detail.

In addressing the scope of the curriculum development the analyst should have some notion about the following: 1. How many terminal learning objectives (few, moderate, extensive); and 2. The type of instructional delivery system (this model is for platform instruction). With this information Work Effort Points and Development Ratios are determined. The complexity of the curriculum is ascertained by conducting a very preliminary and cursory task analysis, in order to obtain a small sample of learning objectives. If the objectives reflect complex learning, the selected Development Ratios are then increased. Once the development ratios are known, then the final cost estimates are calculated. The following paragraphs discuss these procedures in detail.

Work Effort Points for Curriculum Cost Estimation

Work effort points represent the analyst's estimate of the effort (time) required to complete each IPISD step.

The work effort points range from zero to a pre-determined maximum. These pre-determined maximums vary for each step in the IPISD process. Table 1 is a list of the IPISD steps with their respective maximum work effort point values.

A range of work effort points, from zero to some maximum value, allows the estimator to assign the appropriate work effort points required for each specific project, since each individual project will differ. A given step may require maximum effort, no effort, or may be somewhere between zero and maximum. For example, if a prospective course is totally new to the military and is concerned with new technology not taught before (e.g., a laser weapon), there will be no existing courses to analyze. Thus, the work effort points for "Analyze Existing Courses" would be zero. If there are numerous similar existing courses (i.e., a new sonar) which must be analyzed, the work effort points would probably be the maximum, or ten. However, if the subject course has only one or two similar existing courses to analyze (i.e., shiphandling training), the work effort points might be estimated to be half, or five. The maximum points possible for an entire IPISD effort is 150. Since so many courses presently exist which cover multitudes of topics, it is unlikely that the full 150 point maximum would ever be estimated.

TABLE 1. IPISD STEPS WITH THEIR MAXIMUM WORK EFFORT POINT VALUE

IPISD Steps	Maximum Work Effort Points
1 - Job Anaylsis	15
2 - Select Tasks/functions	5
3 - Construct Performance Measures	10
4 - Analyze Existing Courses	10
5 - Select Instructional Settings	3
6 - Develop Objectives	5
7 - Develop Tests	10
8 - Describe Entry Behavior	5
9 - Determine Sequence and Structure	8
10 - Specify Learning Events/Activities	8
11 - Specify Instructional Management Plan	8
12 - Review/Select Existing Materials	10
13 - Develop Instruction	15
14 - Validate Instruction	10
15 - Conduct Internal Evaluation	8
16 - Conduct External Evaluation	10
17 - Revise System	10
TOTAL:	150

Since each IPISD step is unique from the others, it is necessary to vary the maximum work effort points for each step. For example, it can be seen from the list that "Job Analysis" (No. 1) was assigned a maximum of 15 work effort points. Fully analyzing a job, which includes a detailed task analysis, normally takes considerably more resources than would describing the entry behaviors of the learners. The maximum point values represent the consensus of opinion of some half dozen training analysts at the Naval Training Equipment Center who have had years of experience in the curriculum development field. Of course, due to the formative nature of the model, the current maximum levels may be revised as further use of the model dictates.

Briefly, it should be noted that two steps called for by the IPISD model ("Implement Instructional Management" and "Conduct Instruction") have not been included in the cost model because they are concerned with the actual delivery of instruction, as opposed to its development, which is the concern of this model.

Development Ratios

Once the analyst has determined the total number of work effort points for a particular project (the maximum possible being 150), the points are converted to a ratio which approximates the number of development hours required for the effort. The ratio will vary depending upon the amount of effort required to develop the course. The ratios are displayed in Table 2. These ratios represent the development effort required for traditional stand-up lecture instruction. These ratios are useful for curricula which are primarily concerned with the following learning types: motor skills, attitudes and verbal information. As we shall see in the next section, intellectual skills and cognitive strategies require higher development ratios, because they are more complex types of learning.

TABLE 2. CURRICULUM DEVELOPMENT RATIO TABLE FOR PLATFORM INSTRUCTION

Total Work Effort Points	Development Ratio Hours of Development: 1 Hour of Instruction
150 - 130	15:1
129 - 110	14:1
109 - 90	13:1
89 - 70	12:1
69 - 50	10:1
49 - 30	8:1
29 - 0	6.1

Different delivery systems might mean different development ratios would have to be used. (As noted above, the analyst should have a good notion about what kind of instructional delivery systems will be used). Thus, if a computer assisted delivery system were used, the development ratio would be much higher (i.e., some estimates go as high as 200 hours to 1, or higher). The user of the model should change the ratio to fit the particular delivery system. It should be noted that the cost model addresses only the cost of curriculum design and development. Extra training aids, which might be used in a lecture but are not considered to be part of a strict curriculum development effort (media such as slide/tapes, movies, tape recordings, etc.), are to be added in separately as the project requires.

The Effect of the Intellectual Skill Domain (Learning Complexity) Upon Work Effort Point Estimates

Most, if not all, curricula represent a number of different learning types. However, each course can usually be described as concentrating on one type of learning more than any other type. For example, while all five types of learning can be found in a markmanship course, the learning analyst would likely decide that the emphasis is given to motor skill training. A course on safety awareness will concentrate heavily on attitude learning even though other learning types are represented. We feel that the development ratios presented in the previous section work well for the motor skill, attitude, and verbal information domains. However, curricula development for the intellectual skill domain will normally require considerably more work because learning hierarchies are usually present. In order to properly develop curricula which concentrate primarily on intellectual skills, we estimate that at least twice as much development time will be required. Developing the appropriate intellectual skill learning hierarchies, which is vital for intellectual skills learning but not for the other learning types, is a difficult process requiring additional kinds of learning analysis and curriculum design efforts such as remediation loops. Determining the learning complexity of the curricula objectives for intellectual skills is the essential factor in deciding whether or not to increase selected development ratios.

Determining Learning Complexity

How can the analyst determine the complexity of the learning before the IPISD steps are completed? The analyst must conduct the appropriate types of task analysis on a cursory, and limited, basis. Such a cursory analysis can provide the essential information required to determine the learning complexity and adjust the develoment ratios.

Learning complexity of the instruction is *first identified in the task analysis* step of the IPISD model. At this point in the discussion, precision in the use of terms is important. The IPISD manuals simply refer to "Job Analysis" which is the process of breaking a job into duties and analyzing duties into sequentially finer/smaller component parts. In contrast Gagne and Briggs (1979) suggest that a complete "task analysis" is composed of three kinds of analyses on target objectives. First, is the information - processing analysis which is a sequential description of all steps subsumed within the target objectives. This form of analysis is similar to the Job Analysis step in the IPISD process, and specifies what the student would do to accomplish the objective. Secondly, the task classification analysis assigns target objectives to one of Gagne's five domains of learning (i.e. cognitive strategies, intellectual skills, information, attitudes, motor skills). These learning domains have very distinctive implications for the design and conduct of instruction. The third type of task analysis to be performed on target objectives is a learning task analysis which specifies what the student must learn to accomplish the objective. This analysis is usually performed after the above-mentioned kinds of analyses are completed. The learning task analysis identifies the prerequisites or enabling objectives subsumed under the target objective. In summary, the three kinds of analyses suggested by Gagne and Briggs provide the analysts with three different types of information.

While all three types of task analyses are important in the total design effort, the task classification and learning task analyses are particularly pertinent in determining the learning complexity of the instruction. The following steps describe how to use the learning task analysis in estimating the cost of the curriculum. The first step is to acquire a small representative sample of the instructional target objectives. This can be a difficult step when one is estimating cost for the curriculum that is to be developed. In such a case there are at least two possible alternatives. One is to consult with a subject matter expert and develop the representative sample of objectives. Another alternative exists if the design effort is a revision of an existing curriculum or is very similar to a curriculum that is in existence. The sample of target objectives may be drawn from these sources.

Once the sample has been acquired, the second step is to conduct the task classification analysis. If the objectives belong to the intellectual skills or cognitive strategy domains, the estimator can be reasonably sure that learning hierarchies will be present. He/she may then choose to increase the development ratios. If the estimator wants to confirm the presence of learning hierarchies, then he/she should proceed with a learning task analysis on the selected sample of objectives. As noted above, the key function of the learning task analysis is to identify the prerequisites of the terminal objectives. The reader is encouraged to read Gagne-Briggs (1979) for a complete description of the three types of task analyses.

The analyses described above, which are used heavily for intellectual skills but to a far lesser degree for the other learning domains, cause the development ratios to be substantially increased in six of the fifteen IPISD steps. They are: Step 1 - Job Analysis - Obviously, if the job analysis contains intellectual skills, the learning task analysis for every target objective must be conducted in order to identify all learning hierarchies, in addition to the information - processing analysis. Step 6 - Develop Objectives - will be more complicated and time consuming because supporting and enabling objectives must be meticulously identified. Step 8 - Describe Entry Behavior - becomes more complicated with the presence of learning hierarchies. Step 9 - Grouping and Sequencing and Step 10 - Specify Learning Events are also more difficult and time consuming operations when learning hierarchies are present. Step 13 - Develop Instruction - becomes accordingly extended when instruction for intellectual skills is developed.

Cost Estimates

Current estimates for professional instructional development costs average approximately $41.50 per hour. This figure includes overhead. If typing, printing, and other costs are added in, the figure jumps to approximately $62.00 per hour. In this phase of the model, the development ratio for the particular project is derived from Table 2, and that figure is multiplied by cost per hour for development (e.g., if the ratio is 10:1, the figure $62.00 is multiplied by ten (10) to get $620.00. This means that it will cost approximately $620.00 to develop one hour of stand-up lecture instructional curricula.)

The next step in the model is to determine the approximate course length in hours (e.g., 300 hours) and multiply these hours by the dollar per hour figure for development costs (e.g., $620.00). In our example the approximate cost for curriculum development would be $186,000 (300 x $620.00).

Table 3 has been developed as an aid for simplifying the model's process when the curriculum to be developed concentrates primarily on motor skill, attitude or verbal information learning. Table 4 is used when the curriculum concentrates on intellectual skills and cognitive strategies. To use Table 3 or 4,

TABLE 3. MUTIPLICATION TABLE FOR THE COST ESTIMATION MODEL FOR MOTOR SKILLS, ATTITUDES AND VERBAL INFORMATION

Total Work Effort Points		Development Ratio		1984 Cost Factors		No. of Hours Per Course		Development Costs
150-130	=	15:1 (30:1)	x	$62.00	x	( )	=	$
129-110	=	14:1 (28:1)	x	$62.00	x	( )	=	$
109-90	=	13:1 (26:1)	x	$62.00	x	( )	=	$
89-70	...=	12:1 (24:1)	x	$62.00	x	( )	=	$
69-50	=	10:1 (20:1)	x	$62.00	x	( )	=	$
49-30	=	8:1 (16:1)	x	$62.00	x	( )	=	$
29-0	=	6:1 (12:1)	x	$62.00	x	( )	=	$

TABLE 4. MULTIPLICATION TABLE FOR THE COST ESTIMATION MODEL FOR INTELLECTUAL SKILLS AND COGNITIVE STRATEGIES

Total Work Effort Points	Development Ratio	1984 Cost Factors		No. of Hours Per Course		Development Costs
150-130	30:1	$62.00	x	( )	=	$
129-110	28:1	$62.00	x	( )	=	$
109-90	26:1	$62.00	x	( )	=	$
89-70	24:1	$62.00	x	( )	=	$
69-50	20:1	$62.00	x	( )	=	$
49-30	16:1	$62.00	x	( )	=	$
29-0	12:1	$62.00	x	( )	=	$

the estimator must estimate how many hours the projected course will last and how many work effort points will be required to complete the curriculum.

Past Government figures for inflation in the training development area suggest that a 9% inflation figure be used for each future year; however, the reader is reminded that inflation in the last 2 years has been lower than this 9% figure. Using this figure, the following Table 5 lists dollar per hour cost factors for 1985 - 1987.

TABLE 5. FUTURE COST FACTORS

1985	1986	1987
$67.50	$73.50	$80.00

MODEL ADVANTAGES AND PARAMETERS

As discussed earlier, the model has proven useful in the short time it has been used at the Naval Training Equipment Center to estimate costs for technical training curricula. There are some limitations which accompany any model of this kind. Would-be-users should be aware of these limitations. The model has only been in use at the Naval Training Equipment Center for four (4) years. During that time a number of analyst estimates using the model have been input to the Department of Defense (DoD) budget cycle. Unfortunately, because of the long DoD lead times, none of the curriculum development projects for which estimates have been made have yet come to the procurement stage. For this reason, it will be impossible to fully judge the model's accuracy for a few years. The model has been used in retrospect to examine past curriculum development efforts. When these examinations have been done, the model's cost estimates have come fairly close to the proposals which were submitted by DoD contractors in the past.

There is the danger that the model could be used as a shortcut method for anlaysis. That is, the analyst may make guesses after only a very cursory analysis of the problem. True, the model was designed to be of use for very preliminary estimates of future resource needs, but that does not mean that a good deal of analysis work is not necessary. The model's formula should not merely be "cranked" through, with unfounded guesses for every ISD step. This danger is especially possible when the model is used by an inexperienced analyst who does not have a detailed understanding of the ISD principles. One reason for inserting the use of task analysis in the cost estimation process is to reduce guess work.

The estimation model must be adapted to individual situations. The crux of the model is its reliance on the ISD methodology. All other portions of the model (e.g., dollar per hour cost figures, ratios, etc.) can be changed as necessary. The professional judgement of the estimator should be exercised in order to develop the proper coefficients for each of the model's phases.

The estimates should be updated whenever new information, which impacts either the IPISD steps or the future course length, is revealed. For example, once a detailed task analysis is completed, the effort needed to finish the rest of the IPISD steps may be significantly altered. Carrying the same initial cost estimate from the first year it is made until the procurement of the training system will seldom represent a prudent course of action.

From an ideal ISD point of view, the decision about course length should be preceded by a well-structured task analysis. There can be no doubt that such an approach is the best way to proceed. However, certain constraints may make this not possible. Many other outside influences and factors may dictate that a given course of instruction should not exceed a certain number of weeks. Given that a course is a fixed length, this model appears to be the reasonable approach to cost estimations.

Since the military has endeavored to self-pace so many courses, some comments regarding the use of this model with self-paced courses is appropriate. Students leaving a course at different times would make it difficult to determine an accurate course length for the costing process. One approach might be to determine the median course length. Such a method would allow the estimation of enough resources to produce a quality curriculum for all of the students.

The authors performed a literature search in order to compare this model with other models for curriculum development cost estimation. Despite a search of both the Defense Documentation Center and the Education Resources Information Center, no other models were found.

One key advantage of using a model, such as that exhibited in this paper, is that it helps to standardize discussions about cost estimates. It is conceivable that ten different analysts could examine a curriculum cost effort and develop ten (10) completely different estimates when no standard model is used. Each could focus on some different aspect of cost estimation and thus, a variety of estimates could appear. When all of the analysts can agree that certain specific factors must be addressed (e.g., ISD steps, number of course hours, average cost per hour of development time, etc.) in each estimation effort, the estimates have a much better chance of being both reliable and valid. This standardization can also be of help to management. A manager who is interested in distributing scarce resources for development projects can look at ten different projects and estimate different work effort point totals for each project. The manager can then assign resources based on some standard estimate of how much effort each project will require.

Another advantage of the model is that it focuses the estimation effort on the IPISD steps. Too often, curriculum development cost estimates are based on factors which are not necessarily related to the ultimate design and development effort. For example, in the training device world, a method for curriculum development estimating which has been used in the past, bases the estimate on the training device cost (e.g., 10% of the device cost). A variety of problems may arise when such an approach is used. Chief among them being the possibility that the device will only be used for a small portion of the entire course. In that case the estimate may be far too low to develop the curriculum for the entire course.

Summary

The problem of accurately estimating the cost of curriculum development before any substantive analysis work has been accomplished, has plagued the curriculum development field for some time. Often, before an effort can even start, some resource estimate must be made. A general lack of costing expertise on the part of training analysts often leads to highly inaccurate estimates. These inaccurate estimates may ultimately result in training which does not meet quality standards.

This paper has described a cost estimation model for curriculum development which has proven helpful in generating reasonably accurate figures. The model's basic reliance on the actual curriculum development steps called for by the IPISD process enables an experienced analyst to make valid cost estimates. While the version of the model presented in this paper concentrates on the development of traditional lecture type instruction, there is no reason why the model, in a revised form, could not be used with every type of delivery system.

The model is graphically represented in Figure 1.

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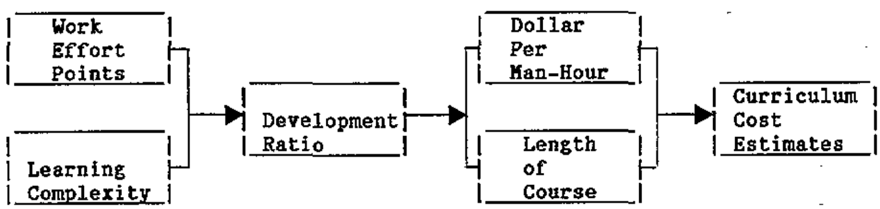

Figure 1. Flowchart of Cost Estimation Process.