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FORMATIVE EVALUATION OF A GAME FOR INTRODUCING METRIC MEASURES TO ADULTS

Nettie-Mae Campbell

A THESIS

in

The Department

of

Education

Presented in Partial Fulfillment of the Requirements for the Degree of Master of Arts in Educational Technology

Concordia University

Montreal, Quebec

August, 1978.

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Abstract

Nettie-Mae Campbell

FORMATIVE EVALUATION OF A GAME FOR INTRODUCING METRIC MEASURES TO ADULTS

This study concerned the formative evaluation of an autotelic activity for introducing adults to common metric measures. The concurrently-developed process model consists of four phases: prototype-design, instrumentation, developmental-evaluation, and demonstration-evaluation. Prototype design creates the first version of the gaming-system. Instrumentation provides instruments for measuring the system's effectiveness. Developmental evaluation runs small-scale tryouts to determine how the prototype should be improved. Demonstration evaluation subjects the final version of the gaming-system to a field trial to determine its effectiveness in meeting "real world" needs.

This paradigm was employed in the formative evaluation of a game which was intended to be participated in for enjoyment, while, at the same time, introducing players to common metric measures. A total of 90 adult-subjects were involved in the study. In demonstration evaluation, a post-test only control group design was employed in administration of game-playing and measurement of subsequent results. The Scheffé procedure of multiple comparisons shows that there is significant difference (p less than .05) in metric-knowledge test-scores between control and experimental groups. The results also indicate that adults enjoy playing the game.

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Shirley Conrad and guests, Frances Coolen and guests, John and Maxine Schwartz and guests, and Douglas and Jackilyn Snair and guests,

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organized and housed deligent card-playing events for tryouts of the prototype-game.

David Stott and Judy Halford of Dartmouth Continuing Education, and the Couples' Clubs of Woodlawn and Grace United Churches provided co-operative experimental and control subjects for testing of the final version of the game.

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Joanne Livingstone made tangible contribution by typing this manuscript.

And finally, my family -- Harry, David and Paul -- enriched this thesis-experience for me by correcting tests, interpreting flow charts, running off copies, acting as chauffeurs and commedians, lending moral support, and so very frequently arriving at the study door with tea "to revive".

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Introduction

Problem Statement

The present study concerned the generation of a process model for the production of instructional gaming-systems, and its application in design and formative evaluation of an instructional activity for facilitating the voluntary conversion of adults to the metric system of measurement. This project originated as result of literature research on the topics of instructional design and development, and observation of the general public's frustration resulting from the use of metric measures in weather reporting and on consumer-item labels.

As succinctly stated by Coleman (1970),

> The enjoyment an individual experiences from a game is such that he will play it quite independently of any desire to learn. The learning occurs as a by-product of the game-playing activity, and need not be a goal at all (p. 185).

Thus, the effectiveness of an instructional game is due primarily to its motivational impact on players (Gamson, 1975). Its ability to involve players in the process is enhanced by the opportunity for improvisation. And the introduction of a small amount of chance, which may improve or damage the player's status, can substantially increase the game's ability to sustain the interest of less well-informed players and permit them to continue to learn from the gaming-system. Clearly, instructional games are communicating devices that provide for the active involvement of learners with subject matter in autotelic activities while freeing them from dependence on authority

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and offering them feedback and ways of measuring their progress toward the goal (Greenblat, 1975c).

Although, as pointed out by Duke (1975) "At the present stage of development in the field of gaming, most if not all games represent 'happenings' rather than the products of deliberate design process" (p. 101), the technologies of instructional design and development are currently in a state of metamorphosis. Numerous educational studies are contributing to the evolution of these technologies. What is needed to speed up this evolution and to improve the quality of instruction is to synthesize steps and guidelines, which current educational literature report to be effective in instructional design and development, so as to generate process models for the production of different instructional strategies such as gaming systems.

One area in which a gaming-system appeared to be a potentially-appropriate and powerful instructional-strategy in Canada was in metric re-socialization. The need for this instructional system resulted from the adoption of a new system of measurement for Canadian usage. This measurement system is the International System of Units suggested by Bureau des poids et measures, Paris (SI: The International System of Units, 1970). Canada's conversion to this new measurement system is the responsibility of the Metric Commission. Gossage (1972-73), first chairperson of the commission, observed that the Canadian population divides into three distinct categories for re-socialization to the metric system of measurement: (a) children who are being introduced to the new system via schools, (b) adults who require the re-education for job performance, and (c) the remainder

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of the population--for whom the re-education is necessary to cope with everyday life in a metric world. The latter segment, which represents a large portion of the Canadian population, includes those adults who are not part of the captive audience for metric re-education and are, therefore, very difficult to reach with education programs (Van der Made, 1975b).

Goals of Study

The goal of this study was to apply a concurrently developed process model in the design and formative evaluation of an instructional game that adults participate in for enjoyment, and which, at tha same time, introduces those adults to common metric measures. The paradigm was based on steps and guidelines that current educational literature report to be effective in the production of instructional gaming-systems. The assumption underlying this goal was that the game would be generated in conjunction with its process model so as to enhance the effectiveness of both the game and the model.

Overview of Study

The term gaming has many and varied definitions. For the purposes of this study, however, gaming may be described as having the following characteristics: (a) competing between individuals or teams for maximum achievement of a given playing objective; (b) established rules governing what players are permitted and forbidden to do during

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the competition, (c) competition-decisions made primarily by players, and to a lesser degree, by chance factors, (d) uncertainty of the outcome of the competition, and (e) a specific terminal point.

The process model that was generated includes four major phases: (a) prototype-design, which creates the first version of the game; (b) instrumentation, which develops measurement instruments for assessing the affectiveness of the gaming system; (c) developmental-evaluation, which runs tryouts of the prototype; and (d) demonstration-evaluation, which assesses the effectiveness of the final version of the game. Each of these phases utilizes a closed-loop system that involves the constant feeding of information back into the instruction to improve its performance.

Application of this paradigm to the problem of introducing non-ceptive adults to the metric system of measurement produced a card game similar to the popular, Forty-Five. Potential dissemination of the metric game is via the Canadian Metric Commission or Department of Consumer and Corporate Affairs, or Provincial Recreation Departments, or a commercial game company, or by all of these.

This was an educational-technology project since, as explained by Mitchell (1973), educational technology concerns the systematization of the educational process which includes the design, production and evaluation of instructional materials and communications for widespread dissemination to meet educational needs.

The time schedule for this educational technology study was as follows:

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Mid September - Mid October (4 wk.): Literature review.

Mid-End October (2 wk.): Formulation of process model.

First-Mid November (2 wk.): Prototype design of metric activity.

Mid November-Mid December (4 wk.): Instrumentation for metric activity.

January (4 wk.): Developmental evaluation of metric activity.

February (4 wk.). Demonstration evaluation of metric activity.

March-Mid April (6 wk): Documentation of study.

Exclusive of the 26-week salary of the educational technologist, the budget for this study was as follows:

	$
1. Literature Research	
Stationery supplies	5.40
Copying	10.25
Transportation	75.00
2. Generation of process model	
Stationery supplies	11.88
Telephone	50.00
3. Design of metric activity	
Stationery supplies	10.80
Typist	10.00
Telephone	50.00
4. Instrumentation for metric activity	
Stationery supplies	10.80
Typing	10.00
5. Developmental evaluation of metric activity	
Stationery supplies	43.20

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Copying	25.65
Typist	75.00
Hostess/host gifts, prizes, lunches: Tryouts	103.43
Transportation	100.00
6. Demonstration evaluation of metric activity	
Stationery supplies	7.00
Copying	26.30
Typist	20.00
Host/hostess gifts,.prizes, lunches: Field trial	72.34
Transportation	45.00
7. Documentation	
Stationery supplies	21.60
Copying	25.10
Typist	260.00
Transportation	40.00
8. Miscellaneous	100.00
TOTAL	$ 1198.74

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Related Research

Instructional Design and Development

In the production of instructional systems, Twelker [n.d. (c)] points out that,

> It is useful to think of a gap--the difference between the learner, where he is before instruction and after instruction...Our problem is to specify the learning conditions necessary to bridge the gap between the learner's initial repertoire and final criterion repertoire (p.1).

The learning conditions necessary are determined via application of the technologies of instructional design and development. However, these technologies are in a state of evolution. Evidence of this can be found in the numerous guidelines and steps for the production of instructional systems that are described in current educational literature: Butler (1977) discusses the major factors that affect learning; Fleming (1970) relates 63 principles for message design; Stolurow (1967) offers over 200 principles for message transfer; Faust and Van Dam (1973) present a practical guide to the science of learning and instruction; Yelon (1973) suggests 45 desirable design features for instructional systems; Brian and Towle (1977) offer numerous guidelines for accelerating the process of instructional design and development; Popham and Baker (1971) present extensive rules for the development of instructional products; Markle (1967) describes three distinct phases in the empirical testing of programs; Marshall and Hales (1972) and Mehrens and Lehmann (1973) provide direction in educational measurement and evaluation.--These writings present only a fraction of the work that could be properly included.

In discussing the present state of the technology of design for instructional gaming-systems, Duke (1970) explains that, "Most if not all games represent 'happenings' rather than products of a deliberate design process" (p. 101). And, in reviewing literature related to instructional development, Baker (1973) notes, "From the current state of the art, one would suppose that minimally such procedures would require specification, field testing and revision as the foundation for developmental work. The possible ways in which each of these points might be translated into practice must be explored" (p. 277).

It follows that one possible means of speeding up the evolution of the technologies of instructional design and development and to improve the quality of instruction is to synthesize steps and guidelines, which educational literature report to be effective in instructional design and development, so as to generate process models for the production of different instructional strategies. The accuracy of such process models would then be determined by operations research which identifies the steps and areas that require modification and/or elaboration.

Gaming-Systems

Games are self-initiating and self-sustaining (Coleman, 1970). People throughout the world learn, practice and relax through play (De Koven, 1975). Recreational games are played by the adult populace in homes, community and recreational agencies, churches, private clubs, commercial casinos and a variety of other institutions

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(Avendon & Sutton-Smith, 1971, p. 246).

As stressed by Tansey and Unwin (1969), "A game suggests it is not serious, that it is not work...use can be made of this, and against the background of fun, learning most certainly can take place" (p. 52). A principle that underlies games is that learning is appropriately a by-product of activity directed toward another goal, and therefore, motivation to learn is intrinsic, derived from motivation to win in the game (Baker & Schutz, 1971; Boocock & Schild, 1968; Coleman, 1970; Tansey & Unwin, 1969).

The effectiveness of an instructional game is due primarily to its motivational impact on players (Gamson, 1975). And its ability to involve players in the process is enhanced by the opportunity for improvisation. Participation involves a high proportion of decisions or plays based on personal choice and a small number based on where the player weighs his/her understanding of the process against his/her judgement of his/her own skill in the process and against the possibility of something happening in a more or less random fashion (--chance--) which would improve or damage his/her position (Feldt & Goodman, 1975). It is the introduction of a small amount of chance that often substantially increases the game's ability to sustain the interest of less well-informed players and allows them to continue to learn from the gaming-system.

Enough isolated research projects into the effectiveness of games has accumulated to indicate that they are probably very powerful instructional vehicles (Twelker, 1970). The affective outcomes of

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instructional games include changes in attitude toward the subject matter of the games and increasing tendencies to become more active and self-directive in the areas of the subject matter [Twelker, n.d. (b)]. And, concepts can be embodied in a game so that players are compelled to recall and/or process them in order to succeed in the game (Bloomer, 1971; Hopkins, 1974). Furthermore, Greenblat (1975 b) observed that in a recent summary of evidence concerning the effectiveness of instructional games,

> There is an increasing amount of positive data on the effects of teaching with games; where the evidence does not reveal benefits of gaming techniques over other modes of teaching, neither does it show the reverse: that is, those taught with games do not prove to have learned less than those taught in traditional ways (p. 188).

Metric System

The (SI) measurement system proposed by the International Bureau of Weights and Measures (SI: The International System of Units, 1970) has been adopted for Canadian usage. This system was chosen because of its advantages over the Imperial System of Measurement and over other metric systems. The major advantages are that calculation in it is much easier since all relationships are in the power of ten, an estimated 90% of the world's population will be using the metric system in the near future, and its symbols make it a truly international measurement language (Gossage, 1974).

Making the citizenry both aware and informed are indispensable elements in promoting harmonious changes in society (Rubins, 1973). Thus, Stevenson (1975) pointed out that:

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> In this exercise of changing over a nation to a new and different system of measurement units, the real objective is public education... It is really, if you can accomplish it, communication with the community in both directions, and the gaining of goodwill and cooperation when you are trying to do it on a voluntary bases (p. 25).

Since a smooth conversion to the metric system of measurement with minimum cost depends upon secondary re-socialization, metric education programs must arrest the natural resistance to change that resides in most people (Hopkins, 1974 a; Hume, 1974; Meyers, 1975; Parker, 1973; Stevenson, 1975).

Because, "a change to metric for many will be sort of a case of Future Shock" (Meyers, 1975, p. 21), many metric-education articles argue for a widespread "think-metric" campaign (Bormet, 1974; Meyers, 1974 a, 1974 b, 1975; Stevenson, 1975). Hopkins (1973) added that such a campaign could make industrial training tasks easier, reduce the burden upon individual concerns, and be an effective way to transfer some costs of metric conversion from the private to the public sector (p. 269). The primary concern of the campaign would focus on facilitation of a kind of intuitive identification of specific metric measurements each with a familiar visual experience or activity; such as, a metre is roughly the height of a kitchen counter (Allen, 1974; De Simone, 1971; Moving to Metric). [This is the same basic step that was employed in making the Imperial System of Measurement easy to learn: Customary units were related to everyday experiences, such as , a foot is about the length of a man's foot and a yard is about the length of a man's arm (De Simone, 1971, p. 37).]

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The International Bureau of Weights and Measures (SI: The International System of Units, 1970, p. 17) and the Canadian Government (Canadian Weights and Measures Act, 1972, pp. 708-9) recognize the non-SI units, litre and tonne, and their corresponding symbols "ℓ" and "t", for common usage. And, the distinction between the terms weight and mass is unimportant for the non-technical population (Metric and Measurement: SI is simple, 1974; Metrication: a guide for consumers, 1974; Metrication: a guide for producers of packaged goods, 1972). Thus, for the citzenry's everyday use, metric measurement includes: (a) Celsius temperatures: -30°, 0°, 20°, 37°, 100°, 175°; (b) volume or capacity: millilitre, litre; (c) length: millimetre, centimetre, metre, kilometre; (d) weight or mass: milligram, gram, kilogram, tonne (Easy to Use Metric Conversion Tables, 1974; Hopkins, 1974; How to write and type SI: A Style Guide, 1974; Odegard, 1974; Wells, 1975).

There was no dearth of aids available for facilitating the citizenry's re-socialization to the metric system of measurement. The following were examples of free or inexpensive metric aids which were readily available:

(a) Citizens' Seminar: Workshop; National Consumer's Association;

(b) How to Metricook: Booklet, Maple Leaf Mills Ltd.;

(c) The Metric Bug: Pamphlet, Bank of Montreal;

(d) Metric Measure: Ruler, Metric Commision;

(e) Go Metric: Temperature Convertor, Royal Trust;

(f) Metrication a guide for Consumers: Booklet, Information Canada;

(g) Think Metric: Slide Converter, Commercial Credit Coroporation

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Ltd.; and

(h) Think the Metric Way: Cube, Metric Commission.

However, the existing aids have had limited impact since the majority of them focus on conversion from Imperial System Units to metric system units, and/or from one metric unit to another. Thus, a learning gap remains between functioning in an Imperial-System world and ready application of the existing metric aids. This gap might be described as the intuitive identification of specific metric measurements each with a form of visual experience or activity. Furthermore, as explained by Van Der Made (1975 b), Nova Scotia representative of the National Consumer's Association of Canada, "Adults who are not part of the captive audience for metrication courses via school or job, and who represent a large portion of the population, are the most difficult to reach with metric education."

So far as the present author could determine (American Metric Journal, 1974-77; Howe & Romiszowski, 1974; Zuckerman, 1973) one potentially effective aid which has not been developed for introducing non-captive adults to the metric system of measurement is a game.

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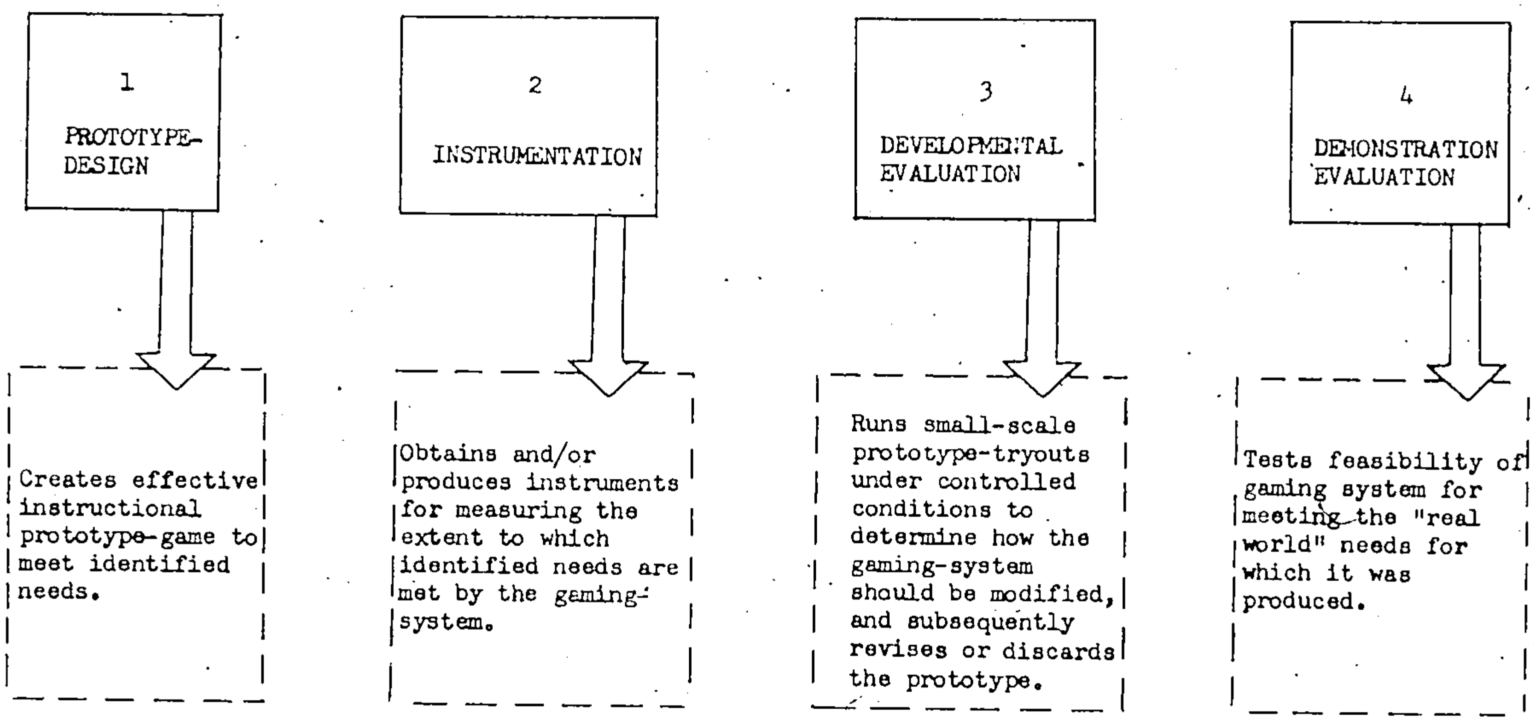
Figure 1

Process Model for Design and Developemnt of Instructional Gaming-Systems



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Process Model

Introduction

Instructional design and development are evolving technologies. Current educational literature describes numerous activities for the production of instructional systems. The intention herein was, therefore, to synthesize steps and guidelines, which the literature report to be effective, into a systems approach for directing instructional-game metamorphesis from its earliest perception to its evolution as an instructional system. The ultimate purpose of the generated paradigm was to specify learning conditions, which accommodate differences in learners' abilities, achievement, motivation, and rates of learning, while exploiting opportunities to increase the effectiveness and efficiency of the gaming-system.

The paradigm consists of four phases as shown in Figure 1. Each phase comprises a multitude of steps. Decisions made in early steps offer criteria and guidelines for making subsequent decisions. The iterative process is controlled by feedback of findings to determine the portion of the output of previous steps that should be altered in light of new information.

Prototype Design

The prototype-design phase creates the first version of the instructional gaming-system. The temporal sequence of this phase is shown in Figure 2.

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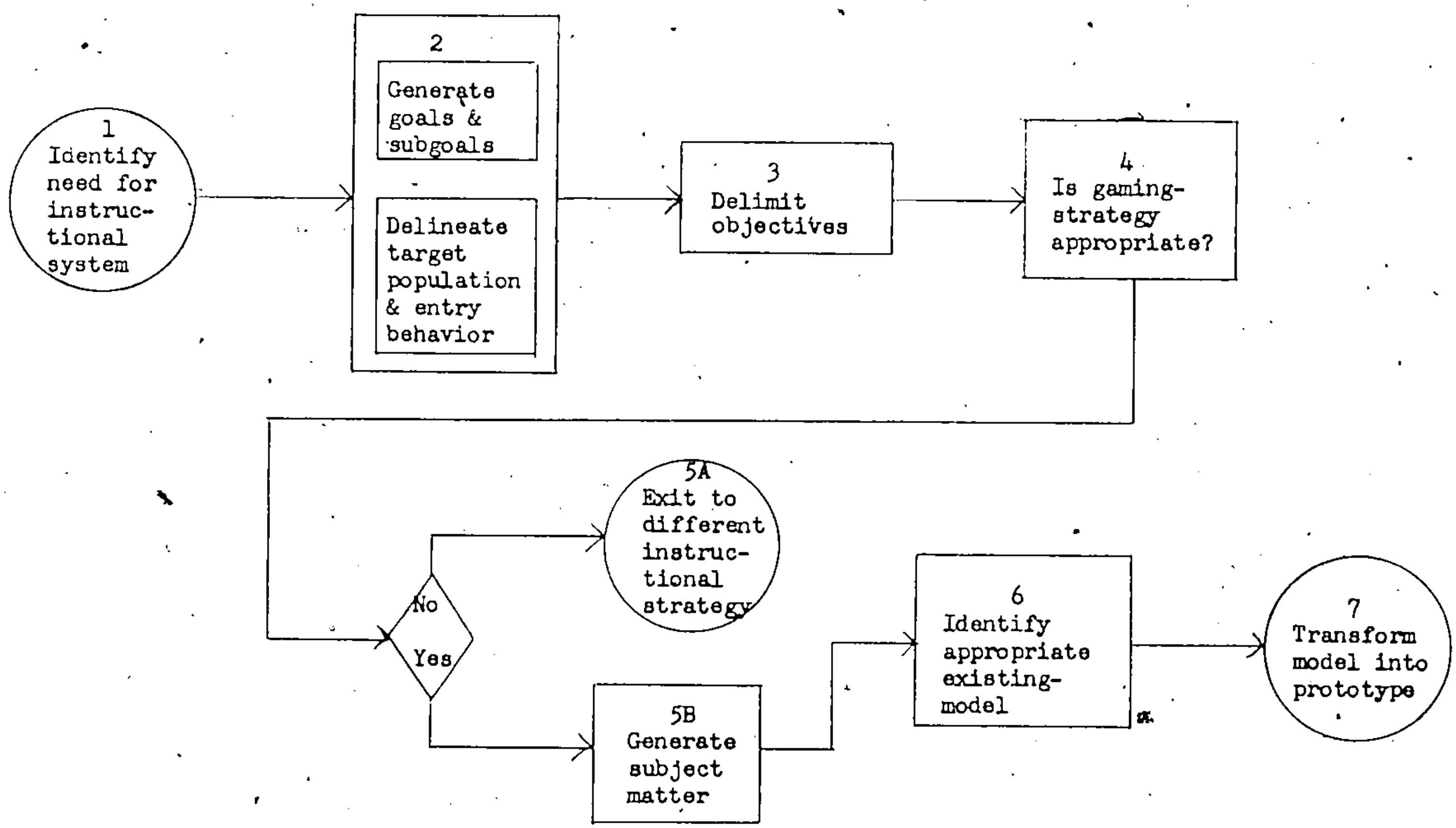
Figure 2

Phase 1: Prototype-Design



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Steps 1-3 formulate the problem. Step 1 identifies the need and underlying problem for which an instructional system is potential solution [Atkinson, 1977; Branson, 1978; Brian & Towel, 1977; Dick & Carey, 1977; Osguthorpe & Bishop, 1978; Twelker, n.d. (e)]. This entails investigation of potential for impact and current contribution factors (Dick & Carey, 1977). Social utility of the instructional system, cost of its preparation (Popham & Baker, 1971), and availability of competing systems (Osguthorpe & Bishop, 1978; Popham & Baker, 1971) should also be considered. The need is validated through judgment of informed individuals via existing literature (Nevo, 1977; Osguthorpe & Bishop, 1978) and in the environment in which the instruction will be conducted (Branson, 1978; Nevo, 1977). This identification of need continues until there is justification for presentation to administrative officials or funding agencies (Dick & Carey, 1977).

Step 2 generates goals and sub-goals (Butler, 1977; Dick & Carey, 1977; Hodgson, n.d.; Locatis & Smith, 1972; Popham & Baker, 1971). Step 3 analyzes the instructional task to produce objectives which must be manifested as evidence of achieving the desired learning (Faust & Van Dam, 1973). These objectives should be derived from real-world requirements and needs, related to the needs and experiences and goals of learners (Yelon, 1973), and analyzed and structured in hierarchial ordered according to complexity (Brian & Towel, 1977; Dick & Carey, 1977; Lindvall & Bolvin, 1969). They should also be jargon-free (Yelon, 1973), describe conditions and behavior and criteria (Atkinson, 1977; Locatis & Smith, 1972; Mager, 1962; Nawaz & Tanveer, 1977; Yelon, 1973) and comprise a complete set of requirements (Lindvall and Bolvin, 1969;

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Yelon, 1973)--general, terminal affective behavior, terminal cognitive behavior, and enabling behavior. The latter describes the basic activity which is intended to bridge the gap between the learner's initial repertoire and the desired terminal repertoire.

The Instructional strategy is selected in Step 4. The question is to decide if the attitudes, knowledge and skills stated above will probably have sufficient impact if couched in the form of an instructional game [Atkinson, 1977; Osguthorpe & Bishop, 1978; Twelker, n.d. (e)]. Real-world constraints with which the gaming-system must contend are identified and validated via data rather than hunches and intuition. Such factors as target population and cost (Atkinson, 1977; Greenblat, 1976; Popham & Baker, 1971), and time and space (Atkinson, 1977) should be examined. If the hurdles are too great for the gaming-strategy to surmount so as to achieve the objectives, the decision is "infeasibility", in which case a different instructional strategy should be chosen.

If it has been decided that the gaming-strategy is feasible, Step 5 delineates all subject matter to be incorporated (Baker, 1973; Duke, 1973; Nevo, 1977). This subject matter should be derived from expert opinions (Baker, 1973; Osguthorpe & Bishop, 1978) and be ordered in the sequence or pattern (Branson, 1978; Butler, 1977) implied by the enabling objectives.

Step 6 identifies an appropriate existing model for the proposed instructional game (Feldt & Goodman, 1975). Then, Step 7 adapts the identified model to produce the prototype for the proposed game. [These steps are suggested by the facts that (a) one of the greatest problems

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in game design is ensuring that the gaming-activity is appropriate for the target population, (b) there are a limited number of basic games and all others are varities thereof (Unwin, 1974), and (c) the discovery of a format which efficiently transmits essential instruction fosters the subsequent revision of the product (Baker, 1973).] Obviously, Steps 6 and 7 are key design steps and should not be rushed because the quality of work they entail will be reflected in the game that is subsequently designed.

The existing recreational or instructional game identified in Step 6 as an appropriate model for the proposed game should have adequate parity with the specifications stated above. This entails being:

(1) already popular with the target population;

(2) data represented on and by gaming pieces readily substituted by all subject-matter data delimited above;

(3) an interaction-process (--process which takes place to form the center-piece of the game--) that (a) involves players in the same type of data manipulation as is implied by half or more of the enabling objectives, and (b) is readily extended to include all types of manipulation implied by said objectives; and

(4) implementation constraints suggested by the target population, goals, and objectives: (a) cost of obtaining and operating, (b) gaming equipment readily employed by target population, (c) location requirements, (d) number of players, (e) competition between individuals and/or groups, (f) time required to learn to play, (g) time required to cycle, and (h) recycling by

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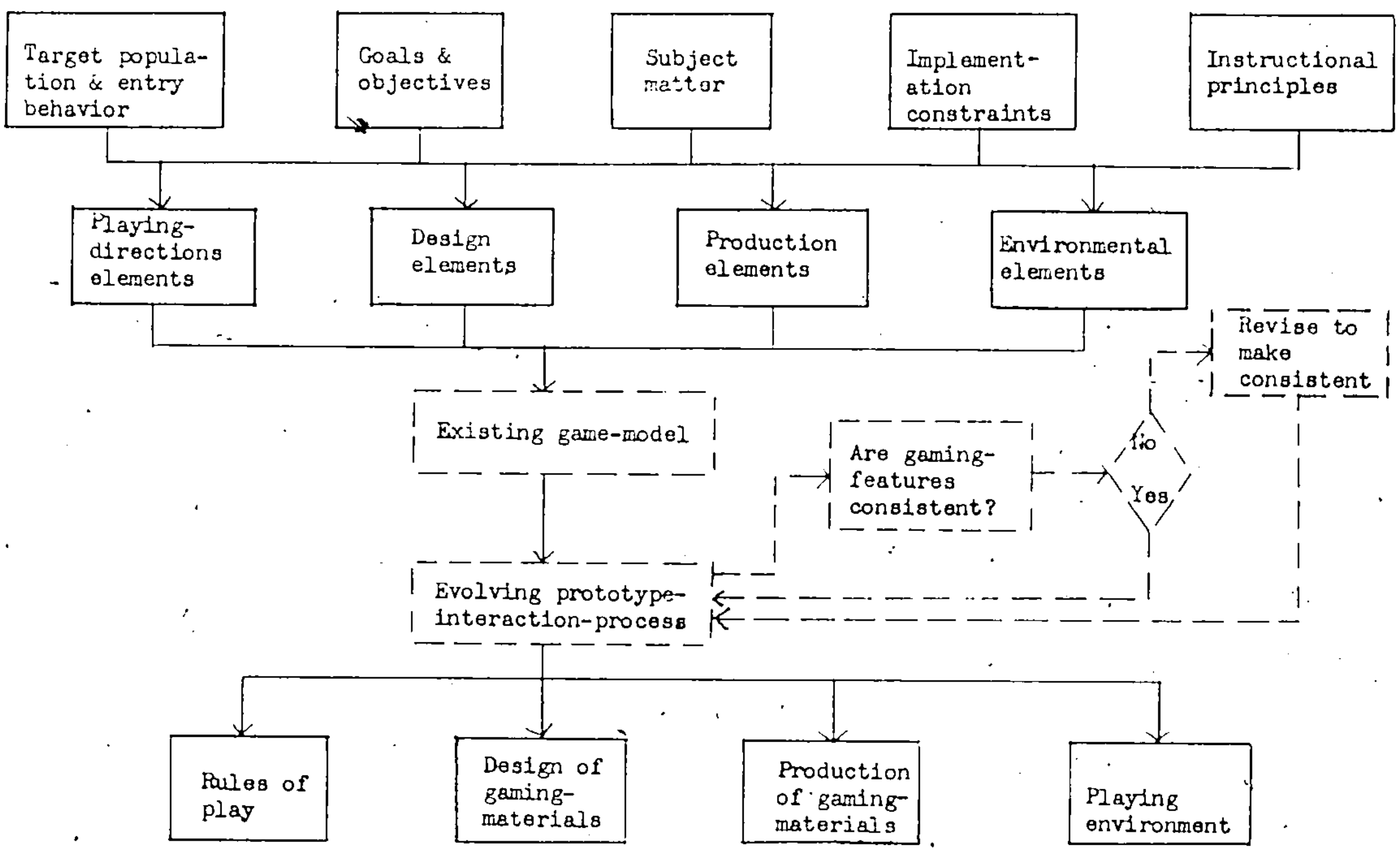
Figure 3

Transform Model into Prototype



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the same players.

If a game model is not readily identified, the parity criteria should be employed to identify and combine elements of different existing games to create the required model.

Step 7 transforms the identified model into the proposed prototype. A graphic illustration of this transformation is shown in Figure 3. The model is adapted to conform to blueprint specifications, including target population and entry behavior, goals and objectives, subject matter, and implementation constraints. [It is important to (a) include both goals and objectives so as to avoid what Baker (1973) describes as being, "trivial, mechanistic and arbitrary in their conscriptions of the developmental task" (p. 256) and (b) repeat constraints from Step 6 to prevent them being neglected or deleted during the complex transformation process.]

Other blueprint specifications to which the prototype must conform are instructional principles. This list of principles divides into six categories: directions in rules of play and on gaming pieces (1-4), focusing learner attention (5-11), communicating knowledge and skills to be learned (12-23), learner-activity (24-39), feedback to learner (40-45), and packaging(46). The instructional principles are as follows:

1. Make directions as brief and explicit as possible (Locatis & Smith, 1972).
2. Avoid new terms and jargon in directions (Locatis & Smith, 1972).
3. Specify directions so that learners can learn from them without

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constant help while making steady progress toward mastering defined objectives (Lindvall & Bolvin, 1969).

4. Design material so that they require minimal directions (Locatis & Smith, 1972; McCormick, 1972).
5. Provide for learner motivation (Baker, 1977; Popham, 1971; Popham & Baker, 1971; Yelon, 1973) initiated by a small chance-factor which improves or damages the learner's position in competition (Feldt & Goodman, 1975), and/or by curiosity (Locatis & Smith, 1972), and/or by the need for achievement.
6. Attempt to gain, direct and maintain learner attention to ensure receptiveness to instruction (Locatis & Smith, 1972).
7. Require learner-reaction to and engagement with information as it is conveyed (Butler, 1977; Stahl & Anzolone, 1970).
8. Ensure purposeful learner-activity via informing the learner what he/she is to do with the new knowledge and skills (Butler, 1977).
9. Ensure that the learner sees goals as attainable (Butler, 1977).
10. Require self-directed behavior of learner [Yelon, 1973; Twelker, n.d. (a)].
11. Involve learner in continuous response activity (Butler, 1977) which is appropriate to objectives (Locatis & Smith, 1972).
12. Avoid hidden cultural biases and discrimination in instructional materials (Locatis & Smith, 1972).
13. Present only stimuli necessary for attainment of specified outcomes so as to <u>avoid</u> wasting valuable instructional time and providing a source of potential learner-confusion (Locatis & Smith, 1972).

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14. Provide for new knowledge to be related to and integrated with the prior knowledge structure (Butler, 1977; Locatis & Smith, 1972).

15. Ensure that examples are familiar to learners from diverse backgrounds (Fleming, 1970; Hodgson, n.d.; Locatis & Smith, 1972; Yelon, 1973).

16. Place the knowledge and skills to be learned in a context that demonstrates their practicality (Butler, 1977).

17. Present terms, facts, concepts, principles, procedures and operations to be learned in a structured sequences or pattern such as functional (-interrelationships-), spatial (-diagrams-), temporal (-sequence of events-), logical (-based on all the above three-) (Butler, 1977), as implied in cognitive-learning objective.

18. Ensure learning of complex knowledge and skills by presenting subject matter via printed message (Fleming, 1970).

19. In presenting subject matter to be learned, use multiple sensory modality inputs <u>only if</u> the rate of input of information is <u>very</u> slow (Fleming, 1970).

20. In presenting knowledge and skills to be learned, ensure effective learning by combining words with related or relevant illustrations (Fleming, 1970).

21. Facilitate concept learning by arranging examples and non-examples of the concept so that critical features are more noticeable (Faust & Van Dam, 1973).

22. To ensure concept and principle learning, communicate the concept or principle followed by a series of examples (Faust & Van Dam, 1973).

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23. Accompany presentations with illustrations and analogies (Butler, 1977) and graphic support [Twelker, n.d. (a); Yelon, 1973].

24. Ensure that learner starts at a level at which his/her present ability of achievement indicates that he/she is functioning and permit him/her to move from there (Faust & Van Dam, 1973).

25. Ensure that learning activity is autotelic, i.e., contains its own goals and sources of motivation (Moore & Anderson, 1975).

26. Ensure that periods of intense learner-involvement are interspersed with more detached or analytic periods (Duke, 1975).

27. Arrange learning-activity events so that they are largely determined by the learner (Moore & Anderson, 1975).

28. Ensure that the learning activity frees the learner to reason things out for him/her self while freeing him/her from depending upon authority (Moore & Anderson 1975).

29. From the outset, permit the learner to explore freely so as to discover a problem from which he/she, in turn, feels the need to identify solution(s) (Moore & Anderson, 1975).

30. Permit the learner to make full use of his/her capacity for discovering various kinds of relationships (Moore & Anderson, 1975).

31. Require learner to distinquish between examples and non-examples of new knowledge and skills to be learned (Instructional Guide #1, n.d.).

32. Ensure learning of similarities (which underlies the formation of concepts, principles, generalizations) by emphasizing the common attributes and de-emphasizing the differences (Fleming, 1970).

33. To achieve stimulus control, employ respondent or operant conditioning (Faust & Van Dam, 1973).

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34. Allow learner to transpose the conceptual content to fit his/her own repertoire [Lindrall & Bolvin, 1969; Twelker, n.d. (a)].

35. Provide opportunities for learner to identify and acquire and repeat actions, such as the following, which he/she assumes are involved in mastering of defined objectives:

    (a) leads to success in a particular situation,

    (b) appeases the motivation condition,

    (c) serves as means to desired ends,

    (d) supports prior success actions, and

    (e) supplements or compensates for valued prior knowledge (Butler, 1977).

36. Require considerable immediate repetition and review via drill for learning of discrete information such as names and dates, <u>but</u> less frequent repetition and review for meaningful learning of concepts and principles and processes (Butler, 1977) while avoiding unnecessary redundancy (Locatis & Smith, 1972).

37. Provide for learner's self-testing and self-evaluation (Nawaz & Tanveer, 1977; Yelon, 1973).

38. Ensure that the learner makes a series of interconnected discoveries about the knowledge and skills being learned (Mooré & Anderson, 1975).

39. Allow the learner the time he/she requires to master the task (Butler, 1977).

40. Reinforce correct learner-behavior (Gagné, 1970; Faust & Van Dam, 1973).

41. Provide learner with knowledge of his/her progress (Butler, 1970).

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42. Provide opportunity for learner to learn why, when his/her action is unsuccessful (Butler, 1977; Locatis & Smith, 1972).

43. Provide temporary prompting of learner's performance when necessary (Butler, 1977; Hodgson, n.d.; Lindrall & Bolvin, 1969; Yelon, 1973).

44. Provide learner with means of verifying concepts and principles during the learning process (Butler, 1977).

45. Emphasize reward, de-emphasize punishment [Twelker, n.d. (c); Yelon, 1973].

46. Design packaging so that materials are easily accessible and interpretable by learners (Baker, 1973).

The complete blueprint specifications described above combine to suggest gaming elements related to playing directions, design, production, and environment. These elements must either be present in the model or be substituted for or integrated with the model's features. The playing directions and design elements, which produce the rules of play and the design of gaming materials, include:

(a) the interaction process of the game (Atkinson, 1977; Greenblat, 1976; Walford, 1969);

(b) player objective in non-subject matter terms--be first to gain winning score (Atkinson, 1977),

(c) indicator of player status--number of houses or points, amount of money, etc. (Boyd, 1976),

(d) acceptability--a very narrow to a very broad population [Twelker n.d. (c)],

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(e) amount of equipment--no equipment such as in discussion to full equipment so that every process is stimulated with materials (Atkinson, 1977, Walford, 1969),

(f) personal contribution of players--bound by predetermined rules in all respects to free from predetermined rules (Walford, 1969),

(g) feedback from peers--none to a great deal [Yelon, 1973; Twelker, n.d.(c)], and

(h) competition--each player operates against others to players operating as one unit (Davis, 1970; Walford; 1969).

The production elements entail (a) amount of equipment (Atkinson, 1977; Walford, 1969), and (b) complexity and expense of production--simple and inexpensive to produce to complex and expensive to produce [Popham & Baker, 1971; Twelker, n.d. (c)]. And, the environmental elements include (a) location constraints--none to very restrictive (Holden, 1973), and (b) environment--threatening to pleasant for learner (Yelon, 1973).

As the model is transformed by the above elements, the prototype's centerpiece, and then profile, evolve. It is at this point that the following game features should be examined for internal consistencies -- material-- [Twelker, n.d. (e)]:

(a) game goal in non-subject-matter terms,

(b) information to be acted on by players,

(c) storage of data or information (e.g. board or receptacle),

(d) means of displaying information,

(e) means of verification of moves or answers of players,

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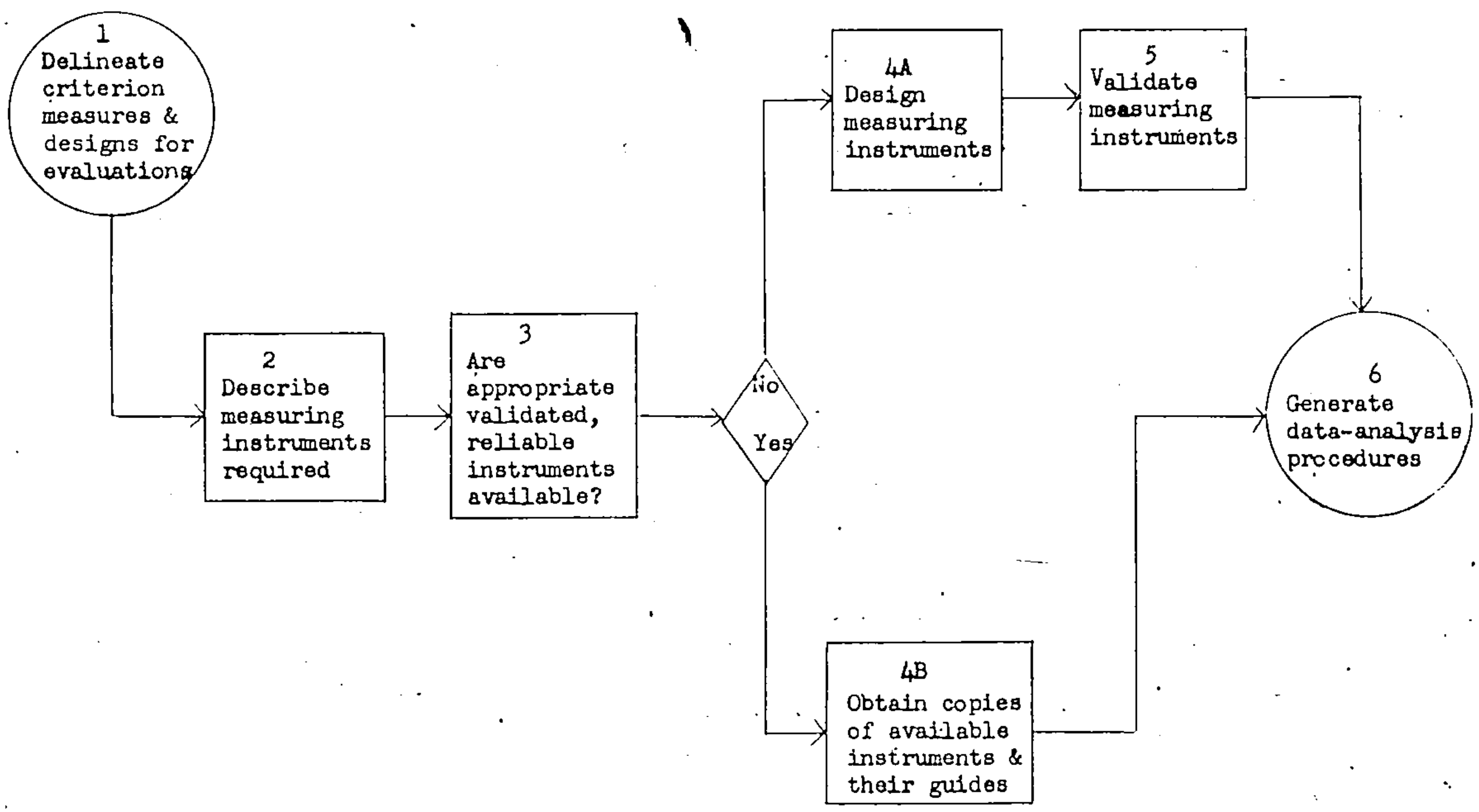
Figure 4

Phase 2: Instrumentation



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(f) information classification which permits players to use information during course of game,

(g) achievement indicators that permit scoring (e.g. clock, score card),

(h) rules of game play,

(i) probability of correct answers,

(j) probability of correct-response sequences by one participant,

(k) chance/known selection of information,

(l) type, frequency, and emphasis of penalty,

(m) type, frequency, and emphasis of rewards, and

(n) emphasis and location of risk.

The same game features should be examined for external consistencies -- meeting learning objectives-- [Twelker, n.d.(e)]. The evolving prototype is then modified to remove the identified internal and external inconsistencies. And finally, based on these consistent game features, (a) the rules of play, (b) design of gaming materials, (c) production of gaming materials, and (d) the playing environment are delineated.

Instrumentation

The instrumentation phase produces and/or obtains instruments for assessing the effectiveness of the gaming-system. The temporal sequence of this phase is shown in Figure 4.

For both developmental and demonstration evaluations, Step 1

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generates the minimal criteria acceptable for demonstrating the attainment of (a) all terminal objectives specified in the above phase [Baker, 1973; Butler, 1977; Dick & Carey, 1977; Locatis & Smith, 1972; Metfessel & Michael, 1967; Namaz & Tanveer, 1977; Twelker, n.d. (e)] and (b) gaming-materials effectiveness. This step also delineates evaluation designs for assessing the effectiveness of both the prototype and the final version of the game (Nevo, 1977). The developmental-evaluation design should also incorporate collection of prerequisite data for facilitating planning of demonstration evaluation, such as the relative number of cycles required for achievement of criterion measures. The major emphasis in the developmental phase should be on the nature of errors (Baker, 1973); while emphasis in the demonstration phase should be equally on the nature and the percentage of player errors. For the latter phase, cognitive criteria should be expressed in the form of hypothesis or hypotheses which compare the results of playing the game with that of not playing the game (Markle, 1967) and/or with the results of other instructional program(s).

Step 2 describes the measuring instruments [Baker, 1971; Metfessel & Michael, 1967; Nawaz & Tanveer, 1977; Nevo, 1977; Twelker n.d. (e); Yelon, 1973] suggested by the criterion measures and evaluation designs. These instruments should focus on all objectives; i.e., on achievement, attitude, skill, interest, and commitment (Sanders & Cunningham, 1973). The major emphasis should be on the collection of data based on observable events, rather than on subjective evaluation by an observer (Popham & Baker, 1971). In addition to test results, information is obtained via questionnaires, observations, and scales for learners

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(Locatis & Smith, 1972; Stolovitch, 1976). Data gathering should include player-responses both during and after game-playing (Baker, 1973). Instruments should be designed so that they produce data which readily lends to modification of the gaming-system (Metfessel & Michael, 1967). And, data-collection that distracts from the game's effectiveness should be avoided (Locatis & Smith, 1972).

Step 3 determines if appropriate, validated, reliable measuring-instruments are available. Instruments should not be utilized because of their availability, but rather because they adequately test the perscribed objectives (Nevo, 1977).

Step 4 obtains appropriate, available measuring instruments identified, and designs other required instruments. Each set of instruments should be accompanied by instructions for administering and scoring.

In Step 5, measuring instruments designed above are validated [Metfessel & Michael, 1967; Nawaz & Tanveer, 1977; Popham & Baker, 1971; Twelker, n.d. (c); Yelon, 1973]. Since the intentional attributes of items generated to measure objectives show great variation, both validity and reliability estimates should be determined (Baker, 1973). Instruments which have not been validated should be avoided since it would not be certain if data collected by them reflect the conditions of the gaming-system or weak assessment instruments (Locatis & Smith, 1972).

Step 6 generates data-analysis procedures, including appropriate statistical methods, for both obtained and designed measuring instruments (Metfessel & Michael, 1967). The emphasis should be on interpreting data in terms of criterion measures so as to formulate recommend-

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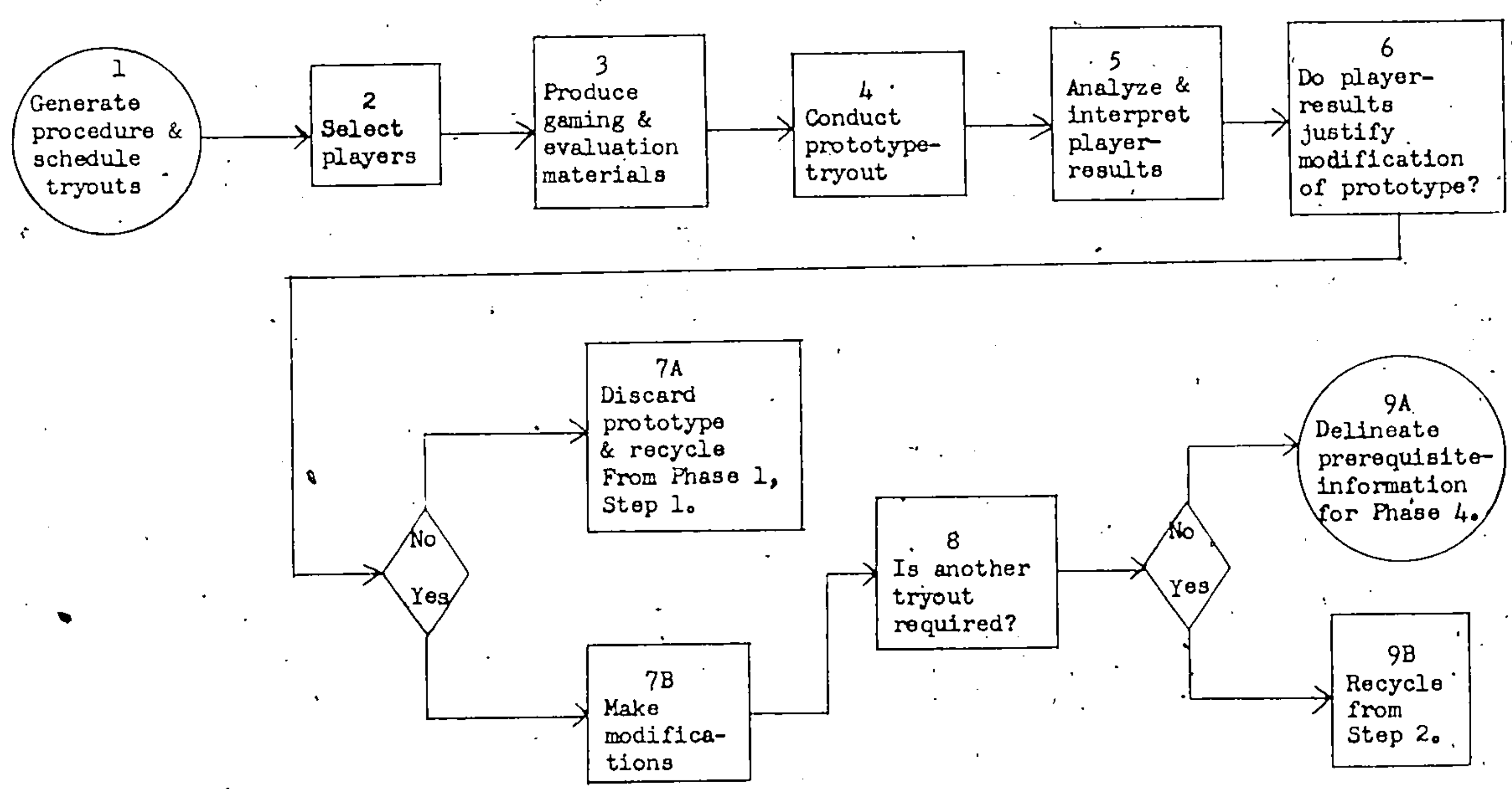
Figure 5

Phase 3: Developmental-Evaluation



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ations that furnish a basis for further implementation and modification of the gaming-system (Popham & Baker, 1971).

Developmental Evaluation

The developmental-evaluation phase runs small-scale prototype-tryouts under controlled conditions to determine how the gaming-system should be modified, and subsequently revises or discards the prototype. In addition, as noted in the above phase, a few decisions regarding the gaming-system are necessary prior to completing planning of the demonstration-evaluation procedure. These decisions are, therefore, based on the relative effectiveness of the prototype. Figure 5 graphically summarizes the major steps in developmental evaluation.

Step 1 reviews the evaluation designs, criterion measures, and measuring instruments for both developmental and demonstration evaluations so as to delineate the procedure for the developmental phase. This procedure should include the collection of prerequisite information for the demonstration phase, such as the number of cycles required to achieve criterion measures. Tryouts, suggested by the procedure, should be scheduled so that time is adequate for making revisions between trials (Locatis & Smith, 1972).

Step 2 selects a small number of tryout-players, perhaps one to six (Baker, 1973). These persons should be close and sympathetic friends to ensure obtaining responsible criticism of the prototype [Feldt & Goodman, 1975; Twelker, n.d. (c)], and should be approximate representatives of the target population. Feldt & Goodman (1975)

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caution that many promising games have been lost or severly damaged by presenting them to a body of unsympathetic critics too early in their development.

In Step 3, evaluation and gaming materials, including rules of play in format intended for operational conditions, are produced for one tryout of the prototype (Dick & Carey, 1977; Osguthorpe & Bishop, 1978; Stolovitch, 1976). Production-specifications delineated in the previous phases should be strictly adhered to.

Step 4 conducts a prototype-tryout as specified in Step 1 above. Players should (a) be assured that it is the game, not the participants, which is the subject of evaluation (Locatis & Smith, 1972; Stolovitch, 1976), and (b) be closely monitored as they learn [Markle, 1967; Twelker, n.d. (c)]. Their questions about the game, but not the content, should be answered (Stolovitch, 1976). Constructive criticism by learners should be encouraged (Locatis & Smith, 1972; Markle, 1967; Yelon, 1973) which includes pointing out ambiguities that call for resolution, indicating difficult points that either require additional development or clarification, and indicating where the game is trivial and uninteresting (Green, 1969). On-the-spot changes in the prototype should be made and then players should try again (Stolovitch, 1967).

In Step 5, player-results are analyzed and interpreted in terms of criterion measures specified in the instrumentation phase so as to formulate recommendations that furnish a basis for further implementation and modification of the gaming-system (Popham & Baker, 1971).

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Step 6 determines if the discrepancy between developmental-evaluation criterion-measures stated in the above phase and player-results justifies modification of the prototype from the cost/effectiveness standpoint (Baker, 1973; Dick & Carey, 1977; Locatis & Smith 1972). If this discrepancy does not justify modification of the prototype, Step 7 discards the prototype as it is infeasible, and then suggests recycling from the first step of the prototype-design phase. On the other hand, if the discrepancy justifies modification, Step 7 makes prototype-revisions which are based on direct inferences derived from learner-performance [Baker, 1973; Dick & Carey, 1977; Green, 1969; Greenblat, 1976; Metfessel & Micael, 1967; Popham & Baker, 1971; Thiagarajan, 1976; Twelker, n.d. (c)] in relation to achievement, attitude, skill, interest, and commitment (Atkinson, 1977; Sanders & Cunningham, 1973; Stolovitch, 1967). These modifications should be made in reference to the prototype-blueprint specified in Phase 1, Step 7.

Step 8 examines Step 1 above to determine if another tryout is required. If another is required, Step 9 recycles from Step 2 above (Dick & Carey, 1977; Green, 1969; Greenblat, 1976). However, if another tryout is not required, Step 9 reviews the results of Step 1 and each cycling of Step 5 to obtain prerequisite information for completing planning of the demonstration-evaluation.

Demonstration Evaluation

The demonstration-evaluation phase tests the gaming-system with

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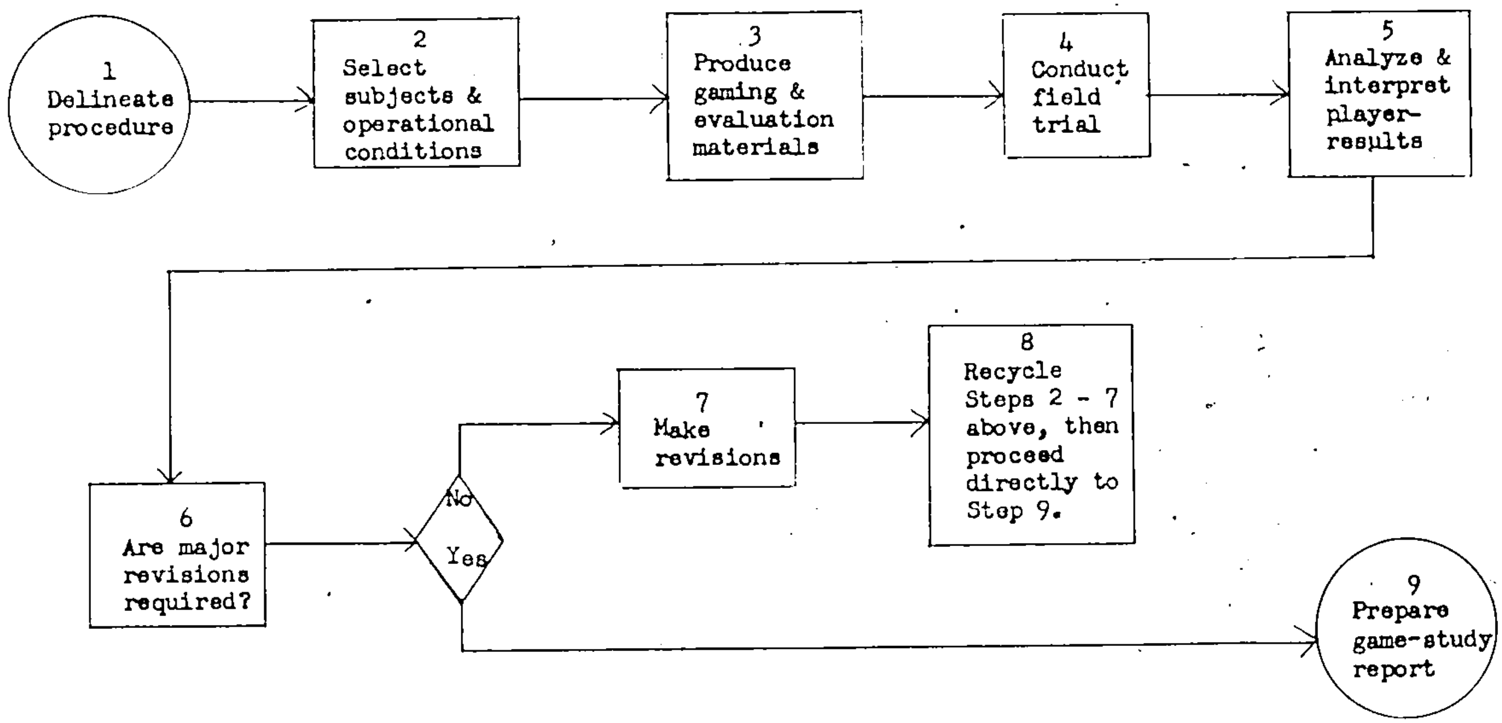
Figure 6

Phase 4: Demonstration-Evaluation



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representatives of the target population under operational conditions to determine its performance characteristics for the real world, and subsequently decides if its adoption or adaption should be recommended (Markle, 1967; Stolovitch, 1976). Figure 6 illustrates the principal steps in this phase.

Step 1 reviews the demonstration-evaluation design, criterion measures, and measuring instruments from Phase 2, and the prerequisite information from Phase 3, Step 9, so as to generate the procedure for demonstration evaluation. Then, Step 2 selects 20 or more evaluation-subjects from the target population and describes operational playing-conditions (Markle, 1967). Next, Step 3 produces evaluation and gaming materials, including rules of play in format intended for operational conditions, for one field trial. Production specifications delineated in the above phases should be strictly adhered to.

In Step 4, a field trial of the gaming-system is conducted as specified by Step 1. Players should (a) be assured that it is the game, not the participants, which is the subject of evaluation (Locatis & Smith, 1972); Stolovitch, 1976), and (b) be closely observed as they learn. Their questions about the game, but not the content, should be answered (Stolovitch, 1976). Constructive criticism by learners should be encouraged (Locatis & Smith, 1972; Markle, 1967; Yelon, 1973). This criticism includes pointing out ambiguities that call for resolution, indicating difficult points that either require additional development or clarification, and indicating where the game is trivial and uninteresting (Green, 1969).

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In Step 5, player-results are analyzed and interpreted in terms of criterion measures as specified in the above phase, for the purposes of (a) determining if the game can stand alone [Twelker, n.d. (c)], and (b) formulating recommendations that furnish a basis for further implementation and modification of the gaming-system (Popham & Baker, 1971). Step 6 determines if, from the cost/effectiveness standpoint (Baker, 1973; Dick & Carey, 1977; Locatis & Smith, 1972), major modifications are required for the gaming-system to stand alone. If major revisions are not required for the gaming-system to stand alone, Step 7 makes modifications suggested by player-results [Green, 1969; Lindvall & Bolbin, 1969; Metfessel & Michael, 1967; Popham & Baker, 1971; Thiagarajan, 1976; Twelker, n.d. (c)] in relation to achievement, attitudes, skill, interest and committment (Atkinson, 1977; Sanders & Cunningham, 1973; Stolovitch, 1967). These revisions should be made in reference to the prototype-blueprint specified in Phase 1.

If Step 7 makes revisions, Step 8 recycles Step 2-7 above, and them proceeds directly to Step 9. On the other hand, if Step 6 decides that revisions are major and, therefore, not to be made, Steps 7 and 8 are omitted.

In Step 9, an extensive game-study report documents the entire study and provides evaluation data regarding the instructional merits of the project (Nevo, 1977). This report should delineate the strengths and weaknesses of the gaming-system, and establish the limit of its usefulness via a complete description of the population with whom it is evaluated (Nevo, 1977). Detailed data, which can be analyzed by other evaluators, should also be included.

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Production of Metric Activity

Introduction

The process model described above was applied in the production of an instructional gaming-activity for facilitating voluntary conversion to the metric system of measurement. This gaming system was intended to be engaged in for enjoyment and, at the same time, to introduce the participants to common metric concepts. The ultimate purpose of the metric game was to help bridge the gap between functioning in an Imperial-Measurement world and employment of readily-available, metric-conversion aids. This application of the process model originated with observation of the citizenry's frustration resulting from the use of metric measures in weather reporting and commercial-item labels.

PROTOTYPE DESIGN

Problem Formulation

Need. The (SI) Measurement System proposed by the International Bureau of Weights and Measures (SI: The International System of Units, 1970) has been adopted by the Canadian Government for Canadian usage. However, as Stevenson (1975) succinctly explained, changing a nation over to a new and different system of measurement units on a voluntary basis involves gaining the community's goodwill and co-operation. Making the citizenry both aware and informed are, therefore, indispensable elements in promoting harmonious changes in society (Rubins, 1973). And, since a smooth conversion to the metric system of measurement with minimum costs depends upon secondary re-socialization, metric education programs must arrest the natural resistance to change that resides in most people (Hopkins, 1974 a; Hume, 1974; Meyers, 1975; Parker, 1973; Stevenson, 1975).

The change to metric has been further complicated by the fact that readily-available, metric-conversion aids focus primarily on conversion from Imperial System Units to metric-system units and/or from one metric unit to another. Thus, an obvious gap remains between functioning in an Imperial-Measurement world and ready application of existing, metric-conversion aids. This gap might be described as the intuitive identification of specific metric measurements each with a form of visual experience or activity. It is because of this gap that statements such as the following are being voiced with increasing frequency: "A change to metric for many will be a sort of case of Future Shock" (Meyers, 1975, p. 21). And, "The quantum leap from one (measurement) system to another is frustrating to most of us" (Robinson, 1978, p. 7).

Bridging the learning gap is, nevertheless, no small problem. The Canadian population divides into three distinct categories for re-socialization to the metric system of measurement: children who are being introduced to the new system via schools, adults who require the re-education for job performance, and the remainder of the population for whom the re-education is necessary to cope with everyday life in a metric world (Gossage, 1972-73). This latter

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segment, which represents a large portion of the Canadian population, includes those adults who are not part of the captive audience for metric re-education, and are, therefore, very difficult to reach with education programs (Van der Made, 1975 b).

It follows that one of the most inexpensive procedures for secondary re-socialization of the Canadian population to the metric system of measurement should involve an activity which (a) has no location constraints, and (b) arrests the natural resistance to changes while introducing customary metric units. Such an activity would ultimately make industrial training tasks easier, reduce the burden upon individual concerns, and be an effective way to transfer some costs of metric conversion from the private to the public sector. Furthermore, need for the activity will probably exist for the next three to four years while only 26 weeks were required to generate and apply the process model in the production of the metric gaming-system. And, exclusive of the salary of the educational technologist, the cost of the entire study was $1198.74. Thus, the time and cost factors were favorable.

Goals. The goal of the process-model application was to produce an instructional activity for facilitating voluntary conversion to the metric system of measurement. The sub-goals of the activity were:

(a) to show that metric units readily relate to everyday experiences,

(b) to arouse interest in and provide motivation for conversion to the metric system of measurement, and

(c) to illustrate the ease with which metric concepts can become

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meaningful to adults.

Target population. The target population included persons 18 years of age and older who had not received metric education via schools and/or job retraining. The entry behavior was readily functioning in an Imperial-Measurement world.

Objectives. The general objective was to produce an instructional activity which would be participated in for enjoyment, and at the same time, would introduce participants to common metric concepts. The terminal, affective-learning objective of the activity was that player-rating be "positive" for 80% of the game variables listed for each of the following:

(a) enjoyment of participation,

(b) acceptable introduction to the metric system of measurement, and

(c) real-life relevance in relation to general-public playing-appeal.

Since one of the first contacts of adults with the metric system of measurement was expected to be with unit symbols, such as M for metre on commercial wrappers, it was decided to include symbols in the learning objectives. Thus, the terminal, cognitive-learning objective was that the participant achieve 80% correctness on a given written test involving the matching of metric unit-names, each with a symbol and an example of visual experience or activity for:

(a) Celsius temperatures: -30°, 0°, 20°, 37°, 100°, 175°,

(b) volume or capacity: millilitre, litre,

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(c) length: millimetre, centimetre, metre, kilometre, and

(d) mass or weight: milligram, gram, kilogram, tonne.

Example:

Place the letter of the appropriate item from Column B on the blank preceeding each Column A item. Each Column B item may be used only once.

Column A	Column B
_____ 100° Celsius	A. freezing point of water
_____ 20° Celsius	B. boiling point of water
_____ 0° Celisius	C. moderate oven temperature
	D. normal body temperature
	E. normal room temperature
	F. none of these

The cognitive-learning objective dictated constraints to be built into the instructional activity. These were expressed in the form of <u>instructional or enabling objectives</u>, which included:

(a) practice in arranging data into four different quantities (--temperature, volume or capacity, length, and mass or weight--),

(b) practice in rank-ordering metric data within each quantity, and

(c) practice in matching metric unit-names each with its corresponding symbol and example.

After having achieved these initial learning-steps, each participant can be expected to employ the free and inexpensive metric aids so as to function readily in a metric world.

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Instructional Strategy

The gaming strategy appeared to be appropriate for the affective-learning objectives since gaming can result in changes in attitudes toward the subject area [Twelker, n.d. (b), p. 6]. The gaming strategy also appeared to be appropriate for the cognitive-learning objective since game rules can be constructed to represent general phenomenon in a subject matter so that players project details into the phenomenon and thus learn from and about it (Goodwin, 1973, p. 934). In addition, games are popular with the target population (Coleman, 1970; De Dovan, 1975), and a game can be made exclusively of printed material so that it has no location constraints (--does not require a captive audience--), and so that it is simple and inexpensive to produce (Holden, 1973). It was, therefore, assumed that gaming was an appropriate choice of strategy for the metric instructional-activity.

Subject Matter

The four metric quantities and their units and corresponding symbols and examples were as follows:

1. Temperature

175° Celsius	C	Moderate oven
100° Celsius	C	Boiling point of water
37° Celsius	C	Normal body temperature
20° Celsius	C	Normal room temperature
0° Celsius	C	Freezing point of water
-30° Celsius	C	Battery trouble temperature

2. Volume or capacity

One litre	ℓ	3 large coffee cupsful
One millilitre	ml	20 raindrops

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3. Length

One kilometre	km	Distance of 10-minute walk
One metre	m	Height of kitchen counter
One centimetre	cm	Thickness of pencil
One millimetre	mm	Thickness of a stick of gum

4. Weight or mass

One tonne	t	Weight of a compact car
One kilogram	kg	Weight of a full round steak
One gram	g	Weight of an unadorned ring
One milligram	mg	Weight of a fly's wing

Identification of Model

Specifications for the model of the prototype-game were generated from the goals, target population and entry behavior, objectives, and subject matter. This model was to be already popular with persons 18 years of age and older, and the data represented on and/or by its gaming-pieces were to be readily substituted by the specified, metric subject-matter. The interaction process of the model was to involve players in at least two of the following manipulations: (a) arranging data into different categories, (b) rank-ordering of data in each category, and (c) forming equivalent sets of data within each category. If one of these interaction features was not exhibited by the model, it was to be readily incorporated via extension of the model.

The following implementation-constraints were intended to maximize the prototype-game's accessibility for the target population. The gaming-materials were to be made exclusively of printed matter so as to be simple and inexpensive to produce, which in turn, would make the prototype-game inexpensive to obtain and to operate. There were to be no location constraints, and the gaming equipment was to be readily employed by persons 18 years of age or older. The model was to be played by six or less players competing in teams, cycled in less than 15 minutes, and readily recycled by the same players. In addition, a maximum of three or fewer cycles were to be required to learn to play the model-game.

Forty-Five is a popular game with Canadian adults (Morehead & Mott-Smith, 1968) which meets the other specifications listed above. This model is a card game which involves players in gaining points via an interaction process of grouping data into four different suits and rank-ordering data in each of the four suits.

Model into Prototype

Transformation. The identified model-game, Forty-Five, was adapted to conform to blueprint specifications including target population and entry behavior, goals and objectives, subject matter, implementation constraints, and instructional-design principles (--see Pp. 21-26). These specifications combined to suggest gaming elements related to playing directions, design, production, and environment (--see Pp. 26 & 27). Some of the elements were exhibited by the model, others were substituted for those in the model, and still others were incorporated as extensions of the model. As these elements transformed the model into the prototype-game, the new interaction-process evolved. The gaming-centerpiece involved players in competition to gain the winning score first via (a) winning tricks by playing the highest ranking metric card or the LAST card in the highest ranking set of metric unit, symbol and example, and (b) forming sets of metric unit, symbol and example

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from cards won regardless of tricks.

Profile. The metric data was represented on 43 playing-cards -- each displayed a different example, symbol or unit. Since quantities were suits, each card also displayed coloured markings identifying its suit. The highest ranking card, the Celsius Symbol, displayed distinctively larger suit-markings than the other cards. For samples of cards, see Appendix A.

The Ranking Chart showed the metric data arranged in suit-groupings. Each suit was outlined in the colour corresponding to that on the cards. Listings within each suit were in decreasing rank-order according to metric magnitude, and sets read across the chart: example, unit, symbol. For sample of Ranking Chart, see Appendix B.

The prototype was appropriate for playing with four or six participants, in teams of two, and with each player seated between opponents. The player-objective was to gain points by winning tricks and by making sets with the cards won.

The Ranking Chart was distributed to each player for reference throughout the game. Each participant was dealt five cards. The next card on the deck was turned face-up as trump. If the Celsius Symbol card was turned face-up, the dealer could take it in exchange for any card he wished to discard from his hand. If a player was dealt the Celsius Symbol card, he could take the turned-up card in exchange for any card he wished to discard.

The player to the left of the dealer lead first. Each other player was required to follow suit or trump, which ever he preferred.

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However, if unable to follow suit or trump, a participant could play as he pleased. The Celsius Symbol card could be played in any turn, regardless of lead or trump.

Each trick was won by its highest ranking card. If the Celsius Symbol card was played, it won the trick since it was the highest ranking card. If the Celsius Symbol card was not played but trumps were played, the trick was won by the highest ranking trump or by the LAST card played in the highest ranking trump set. However, if neither the Celsius Symbol card nor trumps was played, the trick was won by the highest ranking card in the suit lead or by the LAST card played in the highest ranking set of the suit lead.

For each team, one member collected the tricks won, and as the play continued, he/she arranged these cards into sets regardless of tricks. Then, when scores were calculated, a trick was any four cards in a four-player game or any six cards in a six-player game.

Five points were gained for each trick won. In addition, five extra points were gained for each set of two made with the cards won, and 10 extra points were gained for each set of three made with the cards won. Scores were calculated and recorded at the end of each hand of play, except when the winning score of 75 was gained during a hand of play. In the latter case, the game ended at that point, scores were calculated, and the team with the highest score was declared the winner.

Material consistency. The goal of the metric game focused on scoring points via winning tricks and making sets. The playing cards

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displayed data which could readily be classified into suits and subclassified into sets. The metric data which was represented on the cards was displayed on the Ranking Chart in rank-ordered suits.

The rules of the prototype governed (a) when each participant was to play; (b) which suit was to be played, when possible; (c) the winning card in each trick; and (d) how sets could contribute extra points to scores. Cards were randomly distributed to all players via dealing, and were held in fan-shaped fashion, facing the holder. Each trick was won by the highest ranking card or by the last card played in the set of highest rank. A series of tricks could be won by the same player and/or team. Rewards and privileges were emphisized and frequently awarded. These included:

(a) scoring points <u>for</u> tricks won,

(b) scoring extra points <u>for</u> sets made with cards won,

(c) playing lead card <u>for</u> having won previous trick,

(d) receiving the Celsius Symbol card for turning it face-up when dealer,

(e) receiving the turned-up trump <u>for</u> having been dealt the Celsius Symbol card, and

(f) knowing all other cards played in a trick <u>by</u> being the last to play for that trick.

Although there were no penalties in the prototype-play, there was risk for all players except for the player of the Celsius Symbol card and for the last player in the trick. This risk involved choosing to play a high-ranking card, and then having an opponent win the trick via playing a higher-ranking card or the last card in the set of

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highest rank. Risk was also involved in playing a card that opponents might win and then use to gain extra points via making a set. It therefore appeared that the prototype was internally consistent.

External consistency. The game goal served to direct participation in the competition of manipulating metric data in attempting to gain the winning score first. This metric data was displayed on playing cards. Manipulation, as specified by the game rules, involved arranging the metric data into rank-order within quantities and into sets, and required that lead or trump-suit be followed when possible. Each player held his cards fan-shaped and face-in for ready selection, while not displaying them to other players. After each participant played one card in turn, the trick was awarded to the player of the highest-ranking card or of the last card played in the highest-ranking set. It was possible for a player or team to win a sequence of tricks. And each play was readily verified via reference to the Ranking Chart.

Player rewards were emphasized and were frequently awarded. These included points gained for each trick won, and for making sets with the cards won. Each participant frequently took the risk of playing a high-ranking card and having an opponent win the trick by playing a higher-ranking card or the last card in the highest-ranking set. On the other hand, there were no penalties. Therefore it appeared that the prototype was externally consistent; i.e., that the learning objectives probably would be achieved via grouping, matching, and ranking of the metric cards as specified by the playing rules.

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Prototype. The internal and external features together with the profile provided a foundation for generating the rules of play, designing and producing gaming materials, and specifying the playing environment.

INSTRUMENTATION

Evaluation Overview

Formative evaluation of the metric gaming-system involved design and validation of assessment instruments, development of the final version of the prototype-game, and demonstration of the effectiveness of the gaming system. Assessment focused on three effects: cognitive-learning, affective-learning, and gaming-materials. A cognitive-learning questionnaire (-test-) was required for metric-knowledge assessment. For evaluation, affective learning and gaming-materials variables were combined under "debriefing effects". For debriefing-assessment, four instruments were required: a questionnaire, a discussion guide, a game-playing observation and a metric-converter display.

Criterion measures. The game was considered satisfactory when the following criterion measures were achieved:

1. (a) Cognitive learning for developmental evaluation: Three of the four players score 80% on the metric-knowledge test.

   (b) Cognitive learning for demonstration evaluation: (H_1) Playing the game results in higher, metric-knowledge test-scores than not playing the game, and (H_2) playing the

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game with few players results in higher, metric-knowledge test-scores than playing with more players.

2. Affective learning for developmental and demonstration evaluations: Mean player response of "positive" for 80% of the game variables listed for each of the following: (a) enjoyable to play, (b) acceptable introduction to the metric system of measurement, and (c) of real-life relevance in relation to general-public playing appeal.

3. Gaming-materials effectiveness for developmental and demonstration evaluations: All identified deficiencies are removed.

Developmental evaluation. The developmental phase ran small-scale tryouts of the gaming-system to determine how the prototype-game should be modified, and subsequently revised the prototype so that it more effectively and efficiently met the needs for which it was designed. In addition, a few decisions concerning the gaming system were required as prerequisites to completing the demonstration-evaluation procedure. These decisions were based on the relative effectiveness of the prototype: Since the number of cycles had to be determined, it was decided to include a few different numbers of cycles in the tryouts. And since the order of administration of assessments was to be established, it was decided to determine if delaying the cognitive-learning assessment until after debriefing assessment resulted in higher, metric-knowledge test-scores.

During each tryout, four adults played the prototype-game while the administrator sat with them to observe and guide the play. Following each tryout session, player-results were compared with the

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criterion measures to determine if it was feasible to continue the evaluation. If the evaluation was to continue, the prototype system was modified to remove the identified defects.

In the first three tryouts, players cycled the prototype four, seven, and ten times respectively. Following game-playing, cognitive-learning and then debriefing assessments were administered. Since criterion measures were achieved by the third tryout, the fourth (last) tryout involved ten cycles of the prototype followed by administration of debriefing and then cognitive-learning assessments.

Demonstration evaluation. The demonstration phase subjected the final version of the gaming-system to a field trial for the purpose of determining its performance characteristics for the real world, and subsequently recommended that the game be considered for dissemination to the target population. A posttest-only control-group experimental design was employed in this evaluation.

During the field trial, the administrator sat with the players to observe and guide the play. Twelve subjects played 10 cycles of the game in groups of four, and were administered the cognitive-learning and then the debriefing assessments. Twelve other subjects played 10 cycles of the game in groups of six, and were administered the cognitive-learning and then debriefing assessments. Twenty other subjects were administered the cognitve-learning assessment only. Following the field trial, five subjects were randomly selected from each of the experimental groups and 10 were randomly selected from the control group.

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Table 1

Cognitive-Learning-Questionnaire Blueprint

Content (Recognition-Skill Items): Metric unit & example	Symbol & metric unit	Weight (1 point per item)	Item format	D*	V**
Temperature -30° Celsius 0° Celsius 20° Celsius 37° Celsius 100° Celsius 175° Celsius	C	7	Selection	.40 to .80 A few .39 or less (difficult) A few .81 or over (easy)	.30 & over .20 to .29 with modification
Volume or capacity millilitre litre	ml ℓ	4			
Length millimetre centimetre metre kilometre	mm cm m km	8			
Weight or mass milligram gram kilogram tonne	mg g kg t	8			
Total 16	11	27			

* D: Difficulty is the portion of examinees who answer item correctly.

** V: Discrimination is the ability of item to discriminate between better and poorer examinees.

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Cognitive-Learning Questionnaire

It was decided to prepare a multiple-choice, selection-type questionnaire for cognitive assessment. There were several reasons for this type of test: Studies have shown that multiple-choice items are more reliable and valid than other types of items (Brown, 1972) for evaluating convergent thinking. The cognitive-learning objective for the metric game concerned matching items of the lower-level domain. The concepts, on which these objectives focused, were homogenous sets of items that readily lent themselves to construction of grammatically appropriate alternatives for each premis (Marshall & Hales, 1972). The alternative, "none of these", was readily included. Since the items were relatively short, one question could be answered in less than one minute. And, scoring was simple, rapid, and objective (Brown, 1972).

Blueprint. Table 1 illustrates the blueprint for the Cognitive-Learning Questionnaire. Since difficulty indicates the portion of examinees who answered the item correctly, the larger the index, the easier the item. Although the index of 0.50 indicates maximum differentiation among examinees (Marshall & Hales, 1972), omitting items from the preliminary questionnaire would necessarily make the final version more difficult. It was, therefore, decided that appropriate difficulty-indices were (a) 0.40 to 0.80, (b) a few 0.39 or less, and (c) a few 0.81 or over. The formula for calculating indices of difficulty is: $D = \frac{R}{T}$, when R denotes the number of subjects answering the item correctly and T denotes the total number of subjects attempting the item (Huntley, 1976).

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Discrimination indicates the ability of the item to differentiate between the better and poorer examinees, and thus the extent to which success or failure on the item indicates knowledge of the metric concept tested. Since indices of discrimination above 0.60 are good in discriminating between examinees, 0.20 to 0.40 are of some value, and less than 0.20 is so small as to be considered negligible; it was decided to accept discrimination indices of (a) 0.30 and over, and (b) 0.20 to 0.29 with modification. The formula for calculating indices of discrimination is: $V = \frac{R_U - R_L}{(\frac{1}{2})\ T}$, when R_U indicates the number of subjects in the upper group answering the item correctly, R_L denotes the number of subjects in the lower group answering correctly, and T indicates the total number of subjects trying the item (Huntley, 1976).

Pilot testing. The preliminary questionnaire consisted of 63 items. The answer key for this questionnaire was verfied by a Grade VIII student who was excellent in math. It was established, via administration of the questionnaire to an adult who admitted not having prior knowledge of the size of metric units, that there was no fatigue point within the test.

Item analysis and content-coherence reliability coefficient were calculated on the same subjects at the same time. The subjects included 15, third-year engineering students at Saint Mary's University in Halifax, and 15 morning-gymnasts at the "Y" in Dartmouth. This subject-combination of half who were expected to have considerable knowledge of common metric concepts and half who were expected to have little, if any, knowledge of common metric concepts, was intended

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to ensure a fair amount of variability in test scores (Roid & Haladyna, 1977; Huntley, 1976). With both groups of subjects, the administrator distributed copies of the questionnaire face-down, requested that the copies be simultaneously turned face-up, read all instructions aloud, and then requested that each participant complete the questionnaire independently.

Scores were recorded as the number of items answered correctly. Each questionnaire was graded by two independent scorers, and for the two disagreements, arbitration was employed.

Item analysis. The guide for discarding items from this preliminary test is shown in Appendix C. This method of discarding extra items involved the use of rational procedures as a basis for initial selection, and then the use of statistical techniques to check on that judgment (Mehrens and Lehmann, 1973, p. 334). Thus, item-selection involved the following order of activities:

1. Determine the items to be selected from.
2. Discard if omitted by two or more examinees.
3. Accept widest spread of low responses over alternatives.
4. Modify or discard if ambiguous.
5. Modify or discard if more than one correct alternative-answer.
6. Choose most acceptable difficulty and discrimination indices.
7. If still undecided, accept item which most closely maintains the item grouping of the preliminary test.
8. If so dictated by the above steps, discard up to $\frac{1}{4}$ of the items specified for each quantity.

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Appendix D shows the indices of difficulty and discrimination for the preliminary version of the questionnaire. The items which survived the pilot testing were 2, 5, 7, 10, 11, 12, 13, 17, 18, 21, 25, 26, 27, 30, 32, 36, 45, 46, 47, 48, 49, 50, 52, 55, 57, and 63. Five of these items required slight modification. One unintended correct alternative was omitted from each of two items. One foil, which was too strong, was discarded from each of two items. The premise of one item was reworded to make it more specific. In addition, a few modifications were made to the questionnaire introduction-page. One sentence was divided to make it less complex. The request was added for examinees not to look at the questionnaire until asked to do so. And, the instruction regarding placing completed questionnaires face-down on table or desk, was transferred to the bottom of the last questionnaire page. The revised instruction page and a second version of this page--for control subjects--are shown in Appendices E and F respectively.

The numbering sequence of the preliminary questionnaire was not maintained for a number of reasons: It was necessary to maintain the alternating of directions for groups of questions. It was necessary to separate groups of questions in which a foil was too strong for one of the premises. And it, was also necessary to begin the questionnaire with groups of questions, and to avoid placing more than two consecutive individual questions between groups of questions whenever possible, so as to reinforce the instruction that each alternative could be used only once in each group of questions. As result, the above-listed surviving items were renumbered: 4, 5, 6, 1, 2, 3, 25, 26, 22, 23, 19, 20, 17, 16, 15, 14, 7, 8, 9, 12, 13, 10, 11, 18, 21, and 24 respectively.

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The final version of the questionnaire and its scoring key are shown in Appendices G and H. Said key was verified by a Grade V111 student who was excellent in mathematics, including metric measurement.

Reliability coefficient. The Kuder-Richardson 21 procedure was employed to determine the content-coherence, reliability coefficient. This procedure was chosen because each cognitive-questionnaire item was scored +1 or 0, it avoided the problem of having to split the test (Marshall & Hales, 1972), and because this method is appropriate for untimed tests (Tuckman, 1972). The formula for calculating this coefficient of reliability is: $r_{xx} = \frac{n}{n - 1}\left[1 - \frac{\bar{X}(n - \bar{X})}{nS_x^2}\right]$, when n denotes the number of items, $\bar{X}$ indicates the mean score over all subjects, and S_x^2 denotes the variance: the square of the sum of the deviations from the mean for all subjects, divided by the number of subjects (Mehrens & Lehmann, 1973). Appendix I shows that the reliability coefficient was 0.95, which indicated that 95% of the variance of questionnaire scores is associated with knowledge of metric usage as described in the game's cognitive-learning objective and that 5% of the variance is unassociated. And, since a reliability coefficient of 0.65 suffices for group-decisions (Mehrens & Lehmann, 1973), the reliability of the Cognitive-Learning Questionnaire was very acceptable.

Debriefing Instruments

Debriefing assessment focused on the attitude, skill, interest, and committment of players, as well as the effectiveness of gaming materials. For evaluation purposes these were regrouped under the

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following categories: (a) enjoyment in playing the metric game, (b) introduction to metric system of measurement via this game, (c) real-life relevance in relation to citizenry playing-appeal, and (d) gaming-materials effectiveness. For all items under these categories which readily lent themselves to ranking, a rating-scale-type questionnaire was prepared. For the other items, a discussion guide, a game-playing observation, and a metric-converter display were prepared. Copies of the questionnaire and Discussion Guide are contained in Appendices J and K, respectively. Game-playing observation involved observing gaming-system deficiencies during game-playing. The metric-converter display involved observing player-reaction to displayed converters. Appendix L contains copy of the blueprint for debriefing data-analysis.

The scoring scheme for the questionnaire involved (a) converting the built-in, A - E ratings to numerical ratings; (b) average ranking all respondents for each item; and (c) recording a directional symbol with each of the average rankings; i.e., "+" for positive--corresponding with the goals and objectives of the gaming study--, or "-" for negative--conflicting with the goals and objectives of the study--(Mager, 1968).

For the discussion guide, two scoring schemes were included, one for item-responses related to gaming-materials effectiveness, and one for item responses related to enjoyment in playing, introduction to metric system of measurement via this game, and real-life relevance. For the latter scoring scheme, each response-idea required recording (a) a phrase describing the idea, (b) a corresponding directional

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symbol, and (c) a corresponding fraction denoting the portion of respondents agreeing with that idea. Each item-response related to gaming-materials effectiveness required recording (a) a phrase describing each defect, and (b) when available, suggestion(s) for corresponding modification(s). For game-playing observation, the scoring scheme was the same as that described above for gaming-materials effectiveness. For the converter-display, the scoring scheme involved recording a phrase describing the average reaction of participants--acceptance or rejection; i.e., if metric converters were willingly obtained and experimented with so as to employ metric measures.

DEVELOPMENTAL EVALUATION

Problem

Developmental evaluation ran small-scale tryouts of the prototype to determine how the gaming system should be modified, and subsequently revised the prototype so that it more effectively and efficiently met the needs for which it was designed. In addition, a few decisions regarding the gaming-system were necessary prior to completing the demonstration-evaluation planning. These decisions were, therefore, based on the relative effectiveness of the prototype: Since the number of game cycles was to be determined, it was decided to include a few different numbers of cycles in the tryouts. And since the order of administration of assessments was to be established, it was decided to determine if delaying cognitive-learning assessment until after debriefing assessment (--affective-learning and gaming-materials effectiveness) results in higher metric-knowledge test-scores.

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The gaming-system was considered satisfactory when one tryout achieved the following criterion measures:

1. Cognitive learning: Three of the four players score 80% on the metric-knowledge questionnaire.
2. Affective learning: Mean player-response of "positive" for 80% of the game variables listed for each of the following:
   (a) enjoyment in playing,
   (b) acceptable introduction to the metric system of measurement, and
   (c) real-life relevance in relation to citizenry playing-appeal.
3. Gaming-materials effectiveness: All identified deficiencies are removed.

Method

Subjects. The subjects were 16 adult-acquaintances of the present author. Acquaintances were chosen to facilitate free and honest criticism of the gaming system.

Procedure. After each tryout, cognitive and debriefing results were compared with the criterion measures. The degree to which these measures were achieved by the tryout dictated if evaluation should continue. If it was to be continued, an attempt was made to eliminate all identified gaming-system defects prior to the next game-playing session.

Each tryout's agenda was conducted in the same order, except for the tryout following the one in which the cognitive criterion-measures

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was achieved. In this (last) tryout, the order of administration of assessment instruments was reversed. The tryout design for each of the four groups of subjects is shown in Table 6 below:

Table 6: Tryout Design

Tryout group	No. of subjects	No. of consecutive game-cycles	Post-playing assessment
1	4	4	cognitive, debriefing
2	4	7	cognitive, debriefing
3	4	10	cognitive, debriefing
4	4	10	debriefing, cognitive

Each host and/or hostess was requested to arrange a social event involving the tryout of a newly-designed, adult card-game in his and/or her home with three other adults. It was explained that all gaming-materials would be supplied by the present author, and that the purpose was to help identify the game's strengths and weaknesses, and to suggest subsequent improvements. It was also explained that the present author would not play the game because she would be occupied with recording the identified strengths, weaknesses, and suggested improvements. In addition, it was noted that the evaluation session was intended to included questions such as the following:

(a) Were the playing cards satisfactory?

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(b) How complete were the playing instructions?

(c) What made you feel good while playing the game?

(d) What is your opinion of the game?

(e) To whom would you recommend this as an enjoyable game?

Each tryout session was introduced by restating the above explanation, with the exception of the five evaluation questions. It was also pointed out that it was the game, not the players, which was to be evaluated. A copy of the Discussion Guide was then distributed to each player with explanation that the questions thereon would be included in the post-playing discussion of the game. Next, the Game-Population Questionnaire, which is displayed in Appendix M, was administered and then collected in an order in which the Cognitive-Learning Questionnaire could also be readily collected during post-playing evaluation. Gaming materials, including rules-of-play in traditional write-up format, were then placed in the center of the table with the request that players begin the specified number of cycles as they would any other new game.

During each tryout session, the present author sat with the players to guide and observe the play, and thereby to record identified deficiencies and corresponding modifications. This guidance and observation involved:

(a) answering players' questions about the application of the gaming-system, but not its contents;

(b) encouraging constructive criticism by players (--including pointing out ambiguities that called for resolutions, indicating different points that required additional development or

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clarification, indicating where the game was trivial and uninteresting, and suggesting subsequent modifications);

(c) making on-the-spot changes in the prototype and then having the players try again;

(d) collecting data concerning observable events in relation to player performance rather than subjective evaluation by the administrator.

Immediately following each game-playing session, evaluation was introduced by expressing appreciation to participants for the pleasure of observing them play the game and for helping to identify its strengths and weaknesses. Participants were requested to further evaluate the game, and assessment instruments were then administered in the specified order. In the case of the cognitive questionnaire, a copy was distributed face-down to each participant, with the request that they be turned face-up simultaneously. The administrator read the instructions aloud (including that names were <u>not</u> required), and explained that since it was the game, <u>not</u> the players, that was being evaluated, the administrator would remain at a specific location in the room from which she <u>could</u> be seen, but from which she <u>could not</u> read players' answers. Participants were requested to complete the questionnaire independently. After each participant had completed his/her copy, questionnaires were collected in the same order as the Game-Population Questionnaire had been collected prior to game-playing.

Since game-playing observation was necessarily conducted during playing of the game, it was the other debriefing instruments that were administered during the post-playing evaluation. This assessment was

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introduced by explaining that this portion of the evaluation focused on how the players felt about the game. The first debriefing instrument to be administered during the post-game evaluation session was the Debriefing Questionnaire. One copy was distributed to each participant with the request that these be completed immediately and independently. Following the collection of completed questionnaires, the Discussion Guide was administered by casually, not hastily or rigidly, guiding the discussion of each question. During this discussion, two types of data were recorded, one for responses related to gaming-materials and one for responses related to affective-learning objectives. For the latter, the administrator recorded each response-idea, its corresponding directional symbol (--"+" for agreement with the goals and objectives of the gaming-study or "-" for disagreement with these goals and objectives--), and its fractional-rating (--denoting the portion of participants agreeing with that idea and directional symbol--). For gaming-materials-related responses, feedback-defects and modifications were recorded. And, finally, one free, slide-style metric converter for each participant was casually placed in the center of the table, and the administrator then observed if the average participant willingly obtained a converter and if the converters were experimented with so as to employ metric measures.

Analysis. The analysis for each tryout involved cognitive-learning and debriefing data. Game-Population Questionnaires and Cognitive-Learning Questionnaires, both of which had been collected in the same order, were readily paired for each player. One Cognitive-Learning Questionnaire was eliminated for the subject having prior knowledge of the size of metric units. The remaining questionnaires were each scored +1 or 0 per item by two independent persons, and in the case of disagreement, arbitration was employed. For each tryout, the percentage-correct for cognitive-learning test scores was calculated for the highest three out of four scores.

For each tryout, debriefing data-analysis focused on three affective-learning categories (--enjoyment in playing, introduction to metric usage via this game, real-life relevance--), and the gaming-materials effectiveness category. For the analysis of Debriefing Questionnaire data: (a) built-in A - E ratings were converted to numerical ratings, (b) responses for each item were average-ranked over all participants, (c) each average-ranking was assigned a directional symbol (--"+" for agreement with the goals and objectives of the game-study or "-" for conflicting with the goals and objectives of the game-study--), and (d) each average-ranking and its corresponding symbol were permanently assigned to the category dictated by the Debriefing Data-Analysis Blueprint shown in Appendix L. For Discussion Guide data, (a) all response-ideas relating to gaming-materials effectiveness were temporarily eliminated, (b) each remaining response-idea was temporarily assigned to the affective category dictated by the Debriefing Data-Analysis Blueprint, (c) the mean player-response for each category item was determined by examination of the corresponding fractional-ratings and directional symbols, and (d) the mean response and its corresponding symbol were permanently assigned to the specified category. For the converter-display, the mean response was designated a corresponding directional-symbol, and these were then permanently assigned to the category dictated by the Debriefing Data-Analysis

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Table 7: Tryout Results

Tryout group	No. of subjects	No. of consecutive game-cycles	Post-playing assessment*	Cognitive learning	Affective learning: "positive" responses			Gaming-materials effectiveness
				Mean of top 3 scores	Enjoyment in game-playing	Introduction to metric via this game	Real-life relevance	No. of feedback defects
1	4	4	Cog., Deb.	54%	100%	78%	100%	5
2	4	7	Cog., Deb.	73%	100%	75%	100%	5
3	4	10	Cog., Deb.	85%	100%	86%	100%	1
4	4	10	Deb., Cog.	81%	100%	100%	100%	1

* Cog.: Cognitive Instrument
Deb.: Debriefing Instruments

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Table: 9

Feedback and Modifications for Tryouts

		Feedback	Modifications
Tryout 1	A.	"Rank order" in playing instructions not understood	Add two rank-order examples in instructions
	B.	"SET" in playing instructions not understood	Add two SET examples in playing instructions
	C.	Relationship between data on cards and Ranking Chart not understood	Explain this relationship in playing instructions
	D.	Simplify "3 large coffee cupsful"	Substitute "3 large cups of coffee" on card, Ranking Chart, Cognitive-Learning Questionnaire # 10 & 11, 12, 14
	E.	"Game cycles" in Debriefing Questionnaire not understood	Substitute "times" in #5, and "times" & "replay the game" in # 8
Tryout 2	A.	Question: Can Celsius-Symbol card be used to make SETS in red suit only?	Add sentence stating "in red SUIT only" in playing instructions
	B.	Relationship between data on cards and on Ranking Chart, which was explained early in playing instructions, not remembered when play began	Add two separate sentences at bottom of Ranking Chart repeating this relationship
	C.	Facilitate more rapid mastering of playing instructions and ready rereading of specific sections	Provide each player with copy of playing instructions

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		Feedback	Modifications
Tryout 2 Continued	D.	Make game-recycling even more enjoyable	Continue to have winning team for each game-cycle, and add to playing instructions: a) At the end of each game, each player records his/her team score as his/her individual score b) Change partners at the end of each game c) The final winner is the player with the highest score over all games *
	E.	"Unadorned ring" not readily understood	Substitute "man's wedding ring" on card, Ranking Chart, and Cognitive-Learning Questionnaire # 10 & 11
Tryout 3	A.	Question: Where is discarded card placed?	In playing instructions add "to the bottom of the deck"
Tryout 4	A.	"Normal" not meaningful in describing room temperature	Substitute "comfortable" on card, Ranking Chart, and Cognitive-Learning Questionnaire # 4.

* For explanation of the word "game", see Tryout 1. E on this table.

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Blueprint. And, finally for each affective category, the per centage of permanently assigned "positive" responses were calculated.

Analysis of the gaming-materials-effectiveness category included data from game-playing observation and from Discussion-Guide items. (The latter referred to items which the Debriefing Data-Analysis Blueprint designated to the gaming-materials-effectiveness category.) Data analysis for both of these sources involved (a) determining which identified defects were valid, (b) deciding which of the corresponding suggestions for modification were feasible in relation to the game's blueprint-specifications (as stated in the Prototype-Design Phase) and recalled game-playing observation, and (c) assigning the valid defects and their corresponding appropriate revisions as necessary improvements to gaming-materials.

Results

Since all subjects were 18 years of age or older, no Cognitive-Learning Questionnaire scores were eliminated due to subjects' ages. However, since one subject of Tryout 3 indicated on the Game-Population Questionnaire that she had prior knowledge of the size of metric units, the Cognitive-Learning Questionnaire score for that subject was eliminated.

Table 7 shows the combined results for each of the four tryouts. Data analysis for affective-learning objectives is shown in Appendix N, and feedback defects and subsequent revisions are shown in Table 9.

The results of Tryout 1 showed that (a) the cognitive-learning

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criterion-measure was not achieved (54%), although playing the prototype-game may have increased metric-knowledge test-scores, (b) the criterion measures were achieved for two affective-learning objectives (100%, 100%) while slightly underachieved for the remaining affective-learning objective (78%), and (c) five minor deficiencies were identified in the gaming-materials. These findings justified modifying the prototype in an attempt to remove the five defects, and then proceeding with the next tryout.

The <u>results of Tryout 2</u> demonstrated that (a) although the cognitive-learning criterion-measure was not achieved (73%), there was substantial increase over Tryout 1 results (54%), (b) criterion measures were achieved for two affective-learning objectives (100%, 100%) while the remaining affective-learning objective was just slightly underachieved (75%), and (c) five minor defects were identified in the gaming materials. These results warranted revising the prototype to remove the five deficiencies, and then conducting a third tryout.

The <u>results of Tryout 3</u> showed that the cognitive-learning criterion-measure was achieved (85%) with substantial increase over Tryout 2 results (73%), (b) all affective-learning criterion measures were achieved (100%, 100%, 100%), and (c) only one minor defect was identified in the gaming-materials. These findings justified modifying the prototype to remove the identified deficiency, and then proceeding with the next tryout.

Tryout-4 results demonstrated that (a) although administration of the cognitive-learning assessment was delayed, the cognitive-learning criterion measure was achieved (81%) with a very slight decrease over Tryout 3 results (85%), (b) all affective-learning criterion measures were achieved (100%, 100%, 100%), and (c) only one minor defect was identified in the gaming-materials.

Discussion and Recommendations

Developmental-evaluation criterion-measures suggested that the game would be satisfactory when the following were achieved:

1. Cognitive learning: Three of the four players score 80% on the metric-knowledge test.
2. Affective learning: Mean player-response of "positive" for 80% of the game variables listed for each of the following:
   (a) enjoyment in playing,
   (b) acceptable introduction to the metric-system of measurement, and
   (c) of real-life relevance in relation to citizenry playing-appeal.
3. Gaming-materials effectiveness: All identified defects are removed.

It was also the intention in this evaluation phase to determine the number of cycles required to achieve these criterion measures, and if delaying administration of the cognitive-learning test resulted in higher scores on that instrument.

The fourth tryout showed that the prototype-game would be satisfactory after the removal of the one defect identified during that

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final tryout. This legitimized proceeding to the next phase of the metric-game study in which the final version of the game was subjected to a field trial. And, since the prototype-game proved satisfactory when 10 cycles were included, the field trial should include 10 game cycles. In addition, since administration of cognitive-learning and then debriefing instruments during tryouts resulted in very slightly higher metric-knowledge test-scores, this order of assessment should be maintained in the field trial.

DEMONSTRATION EVALUATION

Problem

Demonstration evaluation subjected the final version of the gaming-system to a field trial to determine its performance characteristics for the real world, and subsequently recommended its adoption. This evaluation was, therefore, designed primarily to answer the question, Does playing the game increase one's metric knowledge? And, since the game was intended to be played by four or six players, the secondary question was, Does the number of players affect the amount of metric learning that results from playing the game? Thus, the cognitive-learning hypotheses were:

H_1: Playing the game results in higher metric-knowledge test-scores than not playing the game.

H_2: Playing the game with four players results in higher metric-knowledge test-scores than playing with six players.

In addition, this evaluation was designed to determine if the following debriefing criterion-measures were achieved:

1. Affective learning: Mean player-response is "positive" for 80% of the game variables listed for each of the following:
   (a) enjoyment in playing,
   (b) acceptable introduction to the metric system of measurement, and
   (c) real-life relevance in relation to general-public playing-appeal.
2. Gaming-material effectiveness: All identified defects are removed.

Method

Subjects. Each of the 44 persons involved in demonstration evaluation was either enrolled in a non-academic continuing-education course in Dartmouth, Nova Scotia, or was a member of a United Church Couples' Club in Dartmouth, Nova Scotia. All subjects were 18 years of age or older and were previously unacquainted with the administrator.

Procedure. The following posttest-only control group design was employed:

A	O_1	S_1
B	O_2	S_2
C	O_3	S_3

In this design, A denotes the four-player-game treatment, B signifies the six-player treatment, C denotes the control or non-player treatment, O signifies an observation, and S denotes assignment of subjects. This design was selected for several reasons (Tuckman, 1972, pp. 106-7): It controls for history and maturation by utilization of both control and experimental groups. And,

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this design controls for simple testing effects and interaction between testing and treatment by administering no pretest.

For the purpose of eliminating results of subjects less than 18 years of age and of checking on random assignment, items related to age and salary were added to the Cognitive-Learning Questionnaire Introduction. (Samples of the modified introductions for experimental and control groups are shown in Appendices O and P respectively.) Twelve subjects (A) played 10 cycles of the game in groups of four, and were administered cognitive-learning and then debriefing assessments. Twelve other subjects (B) played 10 cycles of the game in groups of six, and were administered cognitive-learning and then debriefing assessments. And, 20 other subjects (C) were administered the cognitive-learning assessment only.

Following the field trial, Cognitive-Learning Questionnaires in each of the A, B, and C groups, in turn, were held face down while (a) thoroughly shuffled, and then (b) randomly selected from until making up five of A, five of B, and 10 of C. Each of these selected tests was independently scored by two persons, and in the two cases of disagreement, arbitration was employed. Scores were recorded as the number of items answered correctly.

In arranging the field trial, the C group was requested to assist a university student with a study by completing a questionnaire. The A and B groups were approached with the same explanation as had been given to the host and/or hostess of developmental-evaluation tryouts,

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with the two following exceptions: (a) The number of players should be 12-24 and appropriate for playing-groups of four and six, and (b) the game was to be played at the group's usual place of meeting.

Game-playing sessions were introduced by the same procedure as in developmental-evaluation tryouts, with the exception of omitting the Game Population Questionnaire. (The latter had been employed in developmental evaluation for the purpose of eliminating the results of subjects who were less than 18 years of age and/or who had previous knowledge of the size of metric units.) During each demonstration-evaluation playing-sessions, the present author sat with players to guide and observe the play. During and following game-playing, cognitive-learning and debriefing assessments were administered via the same procedure as in developmental-evaluation tryouts.

The control subjects were administered the cognitive-learning assessment only via the same procedure as the experimental groups.

Analysis: Both cognitive-learning and debriefing data were included in the analysis. A number of preliminary calculations were performed on experimental (A + B) and on control (C) test scores. As a check on random assignment, mean ages and mean socio-economic levels were calculated. Mean test scores or probable influence of treatment on metric-knowledge learning were also calculated. And, magnitudes of variance of test scores were calculated by the formula: $S^2 = \frac{\sum (x - \bar{X})^2}{N - 1}$, when $\sum (x - \bar{X})^2$ denotes the sum of squares of each test score from the mean test score, and N symbolizes the number of test scores (Taylor & Larter, 1972, p. 9). In addition, the spreads

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of test scores or standard deviations were calculated by the formula: $S\sqrt{S^2}$ (Tuckman, 1972, p. 226).

The content-coherence reliability-coefficient of the final version of Cognitive-Learning Questionnaire was calculated by Kuder-Richardson 21 procedure, that had also been employed for the first version of the questionnaire, and which applied the formula: $r_{xx} = \frac{n}{n-1}\left[1 - \frac{\bar{X}(n-\bar{X})}{nS_x^2}\right]$. In this formula n denotes the number of items, $\bar{X}$ indicates the mean test score over all subjects; and S_x^2 denotes the variance or the square of the sum of deviations from the mean for all subjects, divided by the number of subjects (Mehrens & Lehmann, 1973, p. 113; Huntley, 1976). This procedure was selected because each questionnaire item was scored +1 or 0, only one type of item was used, and it avoided the problem of how to split the test (Marshall & Hales, 1972, pp. 106-7; Tuckman, 1972, p. 139). This procedure was also chosen because the test was untimed (Tuckman, 1972, p. 139).

In addition, the multiple comparison procedure of Scheffé was employed to test the significant difference between mean, cognitive-learning test-scores for (A + B) and C, A and C, B and C, and A and B. This calculation employed the formula: $F = \frac{(\bar{X}_1 - \bar{X}_2)^2}{S_w^2/n_1 + S_w^2/n_2}$ Ferguson, 1971, pp. 269-271). In this formula: $\bar{X}$ symbolizes the mean test scores in the group, and Sw^2 denotes the within-group variance. The latter was calculated by adding together the sums of squares about the k means and then dividing by the total number of degrees of freedom: N - k, when N denotes the number of test scores in all groups and k indicates the number of groups (Ferguson, 1971, p. 213). The procedure of Scheffé ($p < .10$) was selected because of its compromise

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between controlling for Type 1 error--of finding a difference between means when there is no difference, and for Type 11 error--of not finding a difference when a difference does exist (Ferguson, 1971, Pp. 271-275). And as recommended by Scheffé, the 0.10 (rather than 0.05) level of significance was chosen because, "the Scheffé procedure is more rigorous than other procedures" (Ferguson, 1971, p. 271).

Debriefing data was analyzed by the same procedure as in developmental evaluation.

Results

One cognitive-learning test was eliminated from the B group because of a participant's refusal to complete it. This action resulted from the participant's annoyance with having agreed "to play the game in a social context to help identify its strengths and weaknesses, and then being expected to take a test to determine if we had learned the metric content". However, other participants ignored this behavior, and readily completed their copies of the test. (It was also observed that, prior to the distribution of said test copies, the participant-in-question appeared to be thoroughly enjoying the game.)

One Cognitive-Learning Questionnaire was also eliminated from the C group because the subject was less than 18 years of age. Thus, random selection was from 12 A, 11 B and 19 C cognitive-learning tests.

The mean ages in years for (A + B) and C were 36 and 31 respectively, while the mean socio-economic levels in thousands of dollars were 13 and 11 respectively, which together show that the subjects

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were randomly assigned. The mean cognitive-learning test-scores for (A + B) and C were 22.3 and 14.1 respectively, indicating that the influence of game-playing treatment on metric-knowledge test-scores was probably substantial. The variances for the same groups were 6.46 and 43.43 respectively, which shows that the game-playing treatment clearly exerted a substantial decrease of variance in metric-knowledge test-scores. The standard deviations for the same groups were 2.54 and 6.59 respectively, indicating that game-playing treatment resulted in less dispersed cognitive-learning test-scores than non-game playing treatment.

The Kuder-Richardson 21 procedure produced a content-coherence reliability-coefficient of 0.99, indicating that 99% of the total cognitive-learning test-scores is associated with one cluster of metric skills and knowledge, and that the remainder (1%) is unrelated. (For this calculation see Appendix Q.) And, since the acceptable level for group decisions is 0.65 (Mehrens & Lehmann, 1973), the calculated coefficient shows that the final version of the Cognitive-Learning Questionnaire should be employed with confidence that it is a consistent measure.

The <u>results of the multiple-comparison Scheffé procedure</u> ($p > .10$; i.e., the probability is less than 10 out of 100 that the difference is due to chance) are shown in the following table. (For calculations see Appendix R.)

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Table 11:

Multiple Comparison Results

Comparison	df	F	F^1	$F \overset{?}{\geq} F^1$
(A + B), C	2 / 17	10.97	5.28	5.96 * YES
A, C	2 / 17	7.76	5.28	2.48 * YES
B, C	2 / 17	10.16	5.28	4.88 * YES
B, A	2 / 17	1.88	5.28	NO

* Also significant at .05 level, when $F^1 = 7.18$.

$N_A = 5$,

$N_B = 5$,

$N_C = 10$.

These multiple-comparison results show that the total experimental group achieved very significantly higher cognitive-learning test-scores than the control group ($F > F^1 = 5.96$). The results also show that, of the two experimental groups, four-player and six-player, the mean cognitive-learning test-score of the latter was slightly more significant than the former over the control group ($F > F^1 = 4.88$ & 2.48 respectively). The other finding was that the two experimental groups were equally related to the significance of cognitive-learning test-scores (F not significant at 1.88).

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Table 15:

Feedback and Modifications for Field Trial

Feedback	Modifications
A. The winning score was gained and partners changed too frequently after only one hand of play in the six-player game.	In instructions change winning score of six-player-game to 110.
B. Type of metric data on cards a bit too small to permit ready and rapid play.	Enlarge type of metric data on cards.
C. Type of metric data on Ranking Chart a bit too small to permit ready and rapid play.	Enlarge type of metric data on Ranking Chart.
D. The concept of gram would be more readily understood via an example of a commonly handled object.	Substitute the example "house key" on card, Ranking Chart, and Cognitive Questionnaire # 10 & 11.
E. The concept of milligram would be more readily understood via an example of a commonly handled object.	Substitute the example "snow flake" on card, Ranking Chart, and Cognitive Questionnaire # 10 & 11 and 14.

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The debriefing-assessment results are shown in the following table:

Table 13

Debriefing Results

Affective-learning objectives			Gaming-materials effectiveness
Enjoyment in playing	Introduction to metric via this game	Real-life relevance	Feedback deficiencies
100%	100%	100%	5

These results show that all affective-learning objectives were achieved to the 100% level and that gaming-materials contained five minor defects. Data analysis of affective-learning objectives is shown in Appendix S. The feedback defects and gaming-materials revisions are shown in the Table 15.

Discussion and Recommendations

The primary hypothesis predicted that playing the game would yield higher metric-knowledge test-scores than not playing the game, while the secondary hypothesis predicted that playing with four players would result in higher metric-knowledge test-scores than playing with six players. The findings show that the game-playing condition yielded significantly higher metric-knowledge test-scores than the non-game-playing condition, thus supporting the primary hypothesis. The surprising findings were that, although playing in groups of six

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produced slightly-higher, significant, metric-knowledge test-scores over the non-playing condition than did playing in groups of four, there was no significant difference in mean metric-knowledge test scores for these two groups. Thus, the secondary hypothesis does not hold true for playing with four players to result in higher metric-knowledge test-scores than playing with six players.

The affective-learning criterion measures predicted a mean player-response of "positive" for 80% of the game variables listed for each of: (a) enjoyment in playing, (b) acceptable introduction to the metric system of measurement, and (c) real-life relevance in relation to general-public playing-appeal. The debriefing results show that each of these criterion measures was achieved. The gaming-materials criterion-measure, which predicted that all identified defects be removed, was not achieved since additional minor feedback-deficiencies were identified.

It follows from the acceptance of the primary hypothesis, the achievement of the affective-learning objectives, and the identification of only minor gaming-materials defects that the metric gaming-system was feasible. There was, therefore, justification for identifying the game as an enjoyable activity for facilitating adults' voluntary conversion to the metric system of measurement, and for considering its potential distribution to adults. However, in view of the rejection of the secondary hypothesis and the non-achievement of the gaming-materials objective, there is also justification for the following constraints: Gaming-materials should first be revised to remove identified deficiencies. The game should be recommended for

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both four-player groups and six-player groups.

Further Research

Three a priori considerations are necessary to contemplating further research of the metric game: (a) A moral problem remains unresolved: This concerns the conflict arising from the administration of the metric-knowledge test to subjects who agreed to participate in a social card-game event for the purpose of identifying strengths and weaknesses in a newly-designed game. (b) Although the Debriefing Questionnaire contained valid items and required minimum time to score, it was relatively time-consuming to administer and was the second paper-and-pencil instrument administered in the brief post-game-playing evaluation-session, thus appearing to reduce the smoothness of that session. This instrument's items might, therefore, be incorporated in the Discussion Guide. --In which case, a list of selected Discussion-Guide items should be employed to introduce the game-playing session. (c) Although feedback from a number of Discussion-Guide items were naturally observed during game-playing, all items or item-substitutes ought to be maintained in order to ensure constant and complete evaluation content.

A number of logical extensions follow from this metric-game study: The Demonstration-Evaluation Phase should be replicated by a research team which is more impartial than the present author who was the originator, designer, producer, and evaluator of this study. Further testing might determine if the time required to learn to play the metric game is decreased by explaining, early in the playing-instructions,

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that the game is similar to Forty-Five. It might also be determined if the number of cycles required to achieve the criterion measures is reduced by making the cards more attractive, such as (a) by color-coding the typed data on the playing cards and Ranking Chart, and/or (b) adding double-headed, colour-coded illustrations of the data on example cards.

Further research might establish this game's potential for incorporation in metric-course and/or workshop introductions,--in which case, additional metric units and their corresponding symbols and examples could be readily corporated for scientific populations. The content of the metric game's Ranking Chart might be built into other instructional activities for voluntary learners, such as radio and television programs. And, the Cognitive-Learning Questionnaire might be employed in testing other instructional metric-activities, since it proved herein to be a very consistent measure of metric learning.

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Conclusions

In Retrospect

This study concerned the generation of a process model for the production of instructional gaming-systems, and its application in the production of an instructional activity for facilitating voluntary conversion of adults to the metric system of measurement. The assumption underlying the generation of the process model in conjunction with its application was that this combination would enhance the effectiveness of both the model and the instructional activity.

An instructional game's effectiveness is due primarily to its motivational impact on players (Gamson, 1975), so that learning occurs as a by-product of the gaming activity, and need not be a goal at all (Coleman, 1973). However, as pointed out by Duke (1975), "At the present stage of development in the field of gaming, most if not all games represent 'happenings' rather than the products of deliberate design process (p. 101). The technologies of instructional design and formative evaluation are, in fact, currently in a state of metamorphosis. Numerous educational studies are contributing to the evolution of these technologies. The intention herein was, therefore, to speed up these evolutions and to improve the quality of instruction by synthesizing steps and guidelines, which current educational literature report to be effective in instructional design and formative evaluation, so as to generate a process model for the production of instructional gaming-systems.

The generated paradigm consists of four phases: prototype-design,

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instrumentation, developmental-evaluation, and demonstration-evaluation. The prototype-design phase creates the first version of the game to meet specific instructional needs. The instrumentation phase obtains and/or designs and validates instruments for measuring the effectiveness of the gaming-system. Developmental evaluation runs a series of tryouts to determine how the prototype-game should be improved, and subsequently modifies or discards the prototype. Demonstration evaluation subjects the final version of the game to field trial(s) to determine its effectiveness in meeting the real-world needs for which it was designed.

This generated process-model was employed in the production of an activity which could be participated in for enjoyment, and, at the same time, would introduce the players to common metric concepts. The metric game was intended for adults who are not included in captive populations for school classes or job retraining, and are therefore very difficult to reach with metric-education programs. The demonstration-evaluation phase showed that the game was enjoyable to play, and that playing it resulted in higher metric-knowledge test-scores than not playing it. After being introduced to metric concepts via this game, individuals could then proceed independently to use metric aids, such as converters, which have become readily and inexpensively availably. The game was intended to be disseminated to the citizenry by government and/or a commercial game-company. Ultimately, this game would make industrial training tasks easier, reduce the burden upon individual concerns, and be an effective way to transfer some of the costs of metric conversion from the private to the public sector.

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Cost-Effectiveness Analysis[1]

Program description. The instructional activity produced by application of the process model was a card game for which each playing card displayed a metric-unit name, or metric-unit symbol, or metric-measurement example. The game was played by four or six participants who grouped, matched, and rank-ordered the playing-card data. It required five to ten minutes to cycle, and readily lent itself to multiple-recyclings in one setting. The purpose of this cost-effectiveness analysis was to determine if the game should be offered to an agency for dissemination to the target population.

In formative evaluation of the metric game, the terminal objectives focused on gaming-materials effectiveness, and the attitude, skill, interest, and committment of players. These were included under the headings: gaming-materials effectiveness, affective learning, and cognitive learning. The terminal gaming-materials objective was that all identified defects be removed; i.e., the game stands alone without the assistance of the administrator. The terminal affective-learning objectives were that the player-rating be "positive" for 80% of the game variables listed for each of the following: (a) enjoyable to play, (b) acceptable introduction to metric system of measurement, (c) or real-

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1 Cost-effectiveness is not to be confused with cost-benefits which is an analysis of the cost and the resulting monetary benefits of educational program(s) or program component(s). Cost-effectiveness analysis provides a conceptual framework for analysing the cost and effectiveness of educational program(s) or program component(s), and includes (a) cost of achieving program objectives, (b) over-all effectiveness of the program in achieving its objectives, and (c) program effectiveness with subgroups of learners. (For further discussion, see R.H. Forbes, 1974.)

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life relevance in relation to general-public playing-appeal. The terminal cognitive-learning objective for the tryouts was that the player achieve 80% correctness on a Cognitive-Learning Questionnaire which required grouping and matching of unit-names, symbols and examples of (1) Celsius temperatures: -30°, 0°, 20°, 37°, 100°, 175°; (2) volume or capacity: millilitre, litre; (3) length: millimetre, centimetre, metre, kilometre; and (4) mass or weight: milligram, gram, kilogram, tonne. The major hypothesis for the field trial was that playing the game result in higher, metric-knowledge test scores than not playing the game.

In formative evaluation, the metric game was subjected to four tryouts and one field trial. In each tryout four adults played the prototype-game in a private home. After each tryout, modifications were made to the gaming-system in relation to the prototype-blueprint. The posttest results for the fourth (final) tryout showed that the terminal affective-learning and cognitive-learning objectives were achieved by 10 cycles of the game, and that the gaming-materials objective would be achieved after revision to remove the one minor deficiency that was identified.

The field trial subjected the final version of the game to an evaluation via a posttest-only control-group design. The forty-four subjects were adults enrolled in continuing-education, non-academic courses or members of church couples'-clubs. Ten of these subjects were randomly assigned from each of the game-playing and the non-game-playing conditions. The evaluation results showed that the game-playing condition resulted in significantly higher metric-knowledge

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test-scores than the non-game-playing condition. The findings also indicated that the affective-learning objectives were achieved, and that a few minor revisions were required to the gaming-materials.

The only activities necessary to implement and operate the metric gaming-program are advertising the game to citizenry, providing packaged-copies of the game, and disseminating these copies to citizenry. Thus, the personnel required are those involved in advertising, packaging, copying, and disseminating.

With the exception of paper and pencil for scoring, the game package includes complete materials and playing instructions. And, although the playing instructions included the constraint of only four or six players, with additional game-copies it is possible for many players to participate at the same time, such as in card socials. No location constraints were included with the game.

Target population. The target population was non-captive adults (--persons 18 years of age and older--) who had not received metric education via schools and/or job retraining. However, as each formative-evaluation group suggested, the game appeared appropriate for teenagers as well as adults.

Criterion measures. The criterion measures employed in formative evaluation of the metric game included cognitive-learning, affective-learning, and gaming-materials effectiveness. The cognitive-learning criterion-measures for developmental evaluation was that three out of four players score 80% on the metric-knowledge test. The major cognitive-learning criterion-measure for demonstration evaluation, which

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was stated in the form of an hypothesis, was that playing the game results in higher, metric-knowledge test-scores than not playing the game. The Cognitive-Learning Questionnaire was employed to assess metric-knowledge learning in both developmental and demonstration evaluations. The content validity of this instrument was assured by a design-blueprint which dictated one item for each of 26 (of the 27) metric concepts that had been built into the game. This questionnaire was a consistent metric-knowledge measurement-instrument with a content-coherence reliability coefficient of 0.99.

The criterion measures for affective-learning and gaming-materials effectiveness remained unchanged throughout formative evaluation. The cognitive-learning criterion-measures were that the mean player-rating be "positive" for 80% of the game variables listed for each of the following: (a) enjoyable to play, (b) an acceptable introduction to the metric system of measurement, and (c) of real-life relevance in relation to general-public playing appeal. The gaming-materials-effectiveness criterion-measure was that all identified defects be removed. The instruments employed to measure both affective-learning and gaming- materials effectiveness included a game-playing observation, a questionnaire, a discussion guide, and a metric-converter display.

Costs. Exclusive of the salary of the educational technologist, the cost of the generation of the process model and its application in the production of the metric gaming-system was $1198.74. Therefore, the only capital costs involved for the purchasing agency are said sum and a reasonable return for the educational technologist's time.

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In view of the facts that (a) the game materials were made exclusively of printed matter to ensure simple and inexpensive production and copying, and (b) the current sales of games are very high; it would appear that the capital cost, together with royalties, and operational costs of advertising, copying and packaging, and dissemination would not only be offset by the price paid by consumers, but would also permit considerable profit. Thus, it would appear that only a small short-term investment is required by the purchasing agency.

Decision. The conclusion of this cost-effectiveness analysis is that the metric game should be made available to the Metric Commision, the Department of Consumer and Corporate Affairs, Provincial Recreation Departments, and/or a commercial game company.

Implications for Educational Technology

With the current educational emphasis on effectiveness and efficiency, accountability, and financial restraint, new problems are emerging in educational research and design activities. As result, there is increased need for educational technology with its emphasis on instructional skills and the systematic method of designing and evaluating materials. Thus, the significance of the present study goes far beyond the process model and metric game that were produced.

For the present study, the process model served to summarize the phases involved and pointed to the factors which entered into decisions that eventually became part of the metric gaming-system. This process model can also be used as guidelines that, hopefully, will assist

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others in avoiding problems typically encountered in instructional-game design.

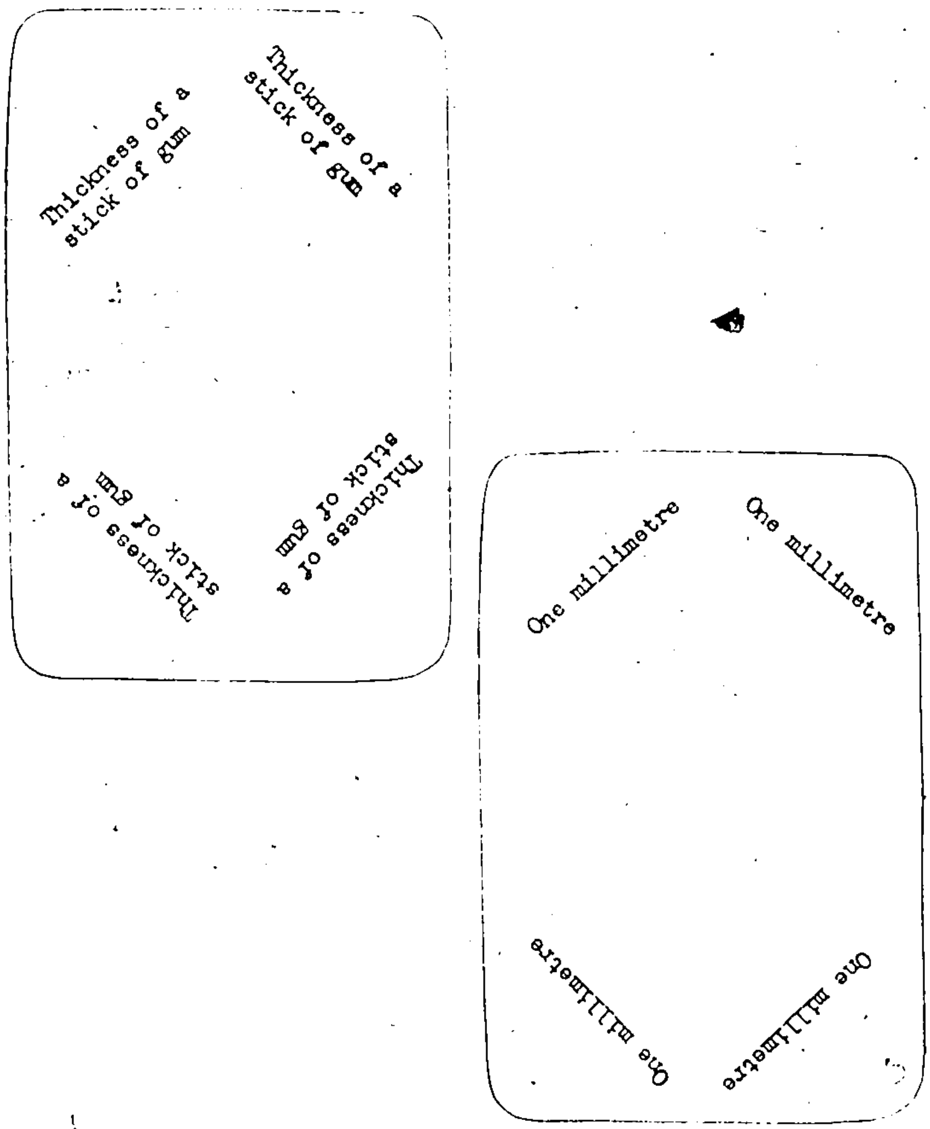
The paradigm is, however, intended as an evolving one. Its accuracy must be determined by further research which identifies the steps and areas that require modification and/or elaboration. The process model can, thus, serve as a catalyst to facilitate evolution of the technologies of instructional-game design and formative evaluation. For example, further guidelines that should be incorporated into the paradigm are suggested in the excellent article by Nevo (1977) which the present author discovered during the writing of this report. These suggestions include:

1. Instructional design should take place within cadres of highly-trained specialists--designers, developers, evaluators, etc!
2. A panel of experts, whose opinions regarding the gaming-system are not yet known, should inspect the prototype prior to running tryouts.
3. A check-list focusing on the quality of the gaming-materials should be prepared for experts recycling the prototype and the final version of the gaming-system.

As the demand intensifies for more careful planning of educational experiences <u>and</u> for non-traditional instruction, educational technology will make an impact on educational institutions and on many in the population in general. The results will be evident--an increased quantity of voluntary learners and an improved quality of learning experiences.

Appendix A

Sample Cards



Note -- S-S symbolizes SETS - SUITS, the name of the metric game.

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Appendix B

Ranking Chart

Example	Unit	Symbol
Moderate oven	175° Celsius	C
Boiling point of water	100° Celsius	C
Normal body temperature	37° Celsius	C
Normal room temperature	20° Celsius	C
Freezing point of water	0° Celsius	C
Battery trouble temperature	-30° Celsius	C
3 large coffee cupsful	One litre	ℓ
20 raindrops	One millilitre	ml
Distance of 10-minute walk	One kilometre	km
Height of a kitchen counter	One metre	m
Thickness of a pencil	One centimetre	cm
Thickness of a stick of gum	One millimetre	mm
Weight of a compact car	One tonne	t
Weight of a full round steak	One kilogram	kg
Weight of an unadorned ring	One gram	g
Weight of a fly's wing	One milligram	mg

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Appendix C

Table 2:
Guide for Discarding Cognitive-Learning Questionnaire Items

	Content	Recognition-Skill Items	Original Test Items	No. of Final Test Items
Metric Unit / Example	Temperature:	-30° Celsius	9, 12	1
		0° Celsius	1, 11	1
		20° Celsius	2, 4	1
		37° Celsius	8, 10	1
		100° Celsius	3, 5	1
		175° Celsius	6, 7	1
	Volume or capacity:	millilitre	39, 52	1
		litre	44, 48	1
	Length:	millimetre	32, 35	1
		centimetre	41, 45	1
		metre	47, 51	1
		kilometre	43, 49	1
	Weight or mass:	milligram	33, 50	1
		gram	36, 38	1
		kilogram	34, 42, 46	1
		tonne	37, 40	1
Symbol / Metric unit	Temperature:	C	29, 30, 61	1
	Volume or capacity:	ml	24, 26, 56	1
		ℓ	14, 17, 58	1
	Length:	mm	22, 25, 62	1
		cm	31, 63	1
		m	13, 16, 60	1
		km	18, 19, 53	1
	Weight or mass:	mg	23, 57	1
		g	20, 21, 59	1
		kg	27, 28, 54	1
		t	15, 55	1
	Total	27	63	27

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Appendix D

Table 3:
Item Analysis for Preliminary Questionnaire

Item	Analysis Upper	Lower	D	V	Item	Analysis Upper	Lower	D	V
1	15	14	0.96	0.06	22	15	8	0.77	0.47
2	15	11	0.86	0.27	23	15	14	0.97	0.07
3	14	8	0.76	0.41	24	15	2	0.57	0.87
4	15	12	0.90	0.20	25	15	5	0.70	0.68
5	15	8	0.77	0.47	26	15	4	0.63	0.73
6	11	7	0.60	0.27	27	15	4	0.63	0.73
7	12	8	0.67	0.27	28	13	4	0.57	0.60
8	13	7	0.71	0.43	29	15	11	0.86	0.27
9	11	11	0.73	0.00	30	15	10	0.83	0.33
10	15	8	0.77	0.47	31	15	15	1.00	0.00
11	15	12	0.90	0.20	32	12	4	0.53	0.53
12	13	9	0.73	0.27	33	13	9	0.73	0.27
13	15	3	0.60	0.53	34	14	5	0.63	0.60
14	12	0	0.40	0.80	35	11	3	0.47	0.53
15	14	13	0.90	0.07	36	8	2	0.33	0.40
16	15	5	0.67	0.67	37	14	12	0.87	0.13
17	15	2	0.57	0.87	38	8	5	0.43	0.20
18	15	1	0.53	0.93	39	10	5	0.50	0.33
19	14	3	0.57	0.73	40	13	14	0.90	-0.07
20	6	3	0.30	0.20	41	11	9	0.69	0.14
21	7	1	0.27	0.40	42	11	6	0.57	0.33

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Item Analysis for Preliminary Questionnaire

Item	Analysis				Item	Analysis			
	Upper	Lower	D	V		Upper	Lower	D	V
43	15	12	0.90	0.20	54	15	14	1.00	0.07
44	12	9	0.70	0.20	55	6	1	0.24	0.34
45	11	7	0.50	0.27	56	15	4	0.66	0.73
46	14	5	0.63	0.60	57	14	6	0.69	0.55
47	15	6	0.70	0.60	58	14	5	0.66	0.62
48	12	9	0.70	0.20	59	12	8	0.69	0.28
49	15	9	0.80	0.40	60	15	10	0.86	0.34
50	12	6	0.62	0.41	61	14	12	0.90	0.14
51	15	7	0.73	0.53	62	15	10	0.86	0.34
52	12	4	0.55	0.55	63	14	9	0.79	0.34
53	15	8	0.79	0.48					

Note -- <u>D: Index of difficulty.</u> This expresses the portion of examinees who answer the item correctly. The larger the portion getting the item correct, the easier the item. Calculated:

$$\frac{\text{No. of examinees answering item correctly}}{\text{Total no. of examinees attempting item}}$$

Mehrens & Lehmann, 1973, p.328).

<u>V: Index of discrimination.</u> This expresses the validity of the item; i.e., the ability of the item to discriminate between better and poorer items. Calculated:

$$\frac{\text{No. of Upper answering item correctly} - \text{No. of Lower answering item correctly}}{\frac{1}{2}\text{ of total no. of examinees}}$$

(Mehrens & Lehmann, 1973, p.329).

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Appendix E

Cognitive-Learning Questionnaire Introduction

The purpose of this questionnaire is to determine how effective the game is. Since it is the game, and not you, that is being evaluated, your name is not required. Your answers will be seen by no one but the administrator and will be used only for the purpose of improving the game. Your score will be the number of questions answered correctly. Try to answer each question and to make your score as high as possible. There is no penalty for guessing. You may change answers by erasing. You will have ample time to complete the questionnaire.

DO NOT look at the questionnaire until asked to do so.

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Appendix F

Cognitive-Learning Questionnaire Introduction

The purpose of this questionnaire is to determine how effective each question is. Since it is the questionnaire, and not you, that is being evaluated, your name is not required. Your answers will be seen by no one but the administrator and will used only for the purpose of improving the questionnaire. Your score will be the number of questions answered correctly. Try to answer each question and to make your score as high as possible. There is no penalty for guessing. You may change answers by erasing. You will have ample time to complete the questionnaire.

DO NOT look at the questionnaire until asked to do so.

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Appendix G

Cognitive-Learning Questionnaire

Section I

Instructions: Under Column B are listed examples of measurement. Under Column A are listed metric readings. Please write the letter of the appropriate answer from Column B on the blank beside each Column A entry. Remember that each Column B answer may be used only once in each group of questions.

Example:

Questions 1 - 4:

Column A

1. C ½ hour
2. E 1 hour
3. A ¼ hour
4. F 2 hours

Column B

A. 15 milutes
B. 100 minutes
C. 30 minutes
D. 45 minutes
E. 60 minutes
F. None of these

There are 26 questions in all.

Do you have any questions about what you are being asked to do or how you are to do it?

-- -- -- -- -- --

Questions 1 - 3:

Column A

1. ___ Normal body temperature
2. ___ Freezing point of water
3. ___ Battery trouble temperature

Column B

A. 20° Celsius
B. 0° Celsius
C. -30° Celsius
D. None of these

Question 4:

Column A

4. ___ 20° Celsius

Column B

A. Freezing point of water
B. Normal body temperature
C. Moderate oven
D. Normal room temperature
E. None of these

Question 5:

Column A

5. ___ Boiling point of water

Column B

A. 175° Celsius
B. 100° Celsius
C. 37° Celsius
D. 20° Celsius
E. None of these

Question 6:

Column A

6. ___ 175° Celsius

Column B

A. Boiling point of water
B. Normal body temperature
C. Freezing point of water
D. None of these

Questions 7 - 9:

Column A

7. ___ Thickness of a pencil

8. ___ Weight of a full round steak

9. ___ Height of a kitchen counter

Column B

A. One metre
B. One litre
C. One kilogram
D. One millilitre
E. One centimetre
F. One kilometre
G. None of these

Questions 10 and 11:

Column A

10. ___ One milligram

11. ___ One millilitre

Column B

A. 20 raindrops
B. Height of a kitchen counter
C. 3 large coffee cupsful
D. Thickness of a stick of gum
E. Weight of a fly's wing
F. Weight of an unadorned ring
G. None of these

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Questions 12 and 13:

Column A

12. ___ 3 large coffee cupsful

13. ___ Distance of a 10-minute walk

Column B

A. One metre
B. One litre
C. One millilitre
D. One centimetre
E. One kilometre
F. None of these

Question 14:

Column A

14. ___ One gram

Column B

A. Weight of a compact car
B. Thickness of a stick of gum
C. Weight of a fly's wing
D. 3 large coffee cupsful
E. None of these

Question 15:

Column A

15. ___ Thickness of a stick of gum

Column B

A. One milligram
B. One litre
C. One kilogram
D. One millimetre
E. One centimetre
F. None of these

Questions 16 and 17:

Column A

16. ___ C

17. ___ kg

Column B

A. centimetre
B. kilomile
C. Celsius
D. kilogram
E. None of these
F. None of these

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Question 18:

Column A	Column B
18. ___ tonne	A. tnn
	B. kr
	C. kg
	D. km
	E. klm
	F. tn
	G. None of these

Questions 19 and 20:

Column A	Column B
19. ___ mlm	A. millilitre
	B. milligram
20. ___ ml	C. millimile
	D. millimetre
	E. None of these
	F. None of these

Question 21:

Column A	Column B
21. ___ milligram	A. lr
	B. g
	C. mg
	D. mm
	E. ml
	F. mgm
	G. mltr
	None of these

Questions 22 and 23:

Column A	Column B
22. ___ kmtr	A. kilomile
	B. kilometre
23. ___ g	C. kilogram
	D. gram
	E. None of these
	F. None of these

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Question 24:

Column A	Column B
24. ___ centimetre	A. ctr
	B. Cs
	C. C
	D. m
	E. cm
	F. mr
	G. mm
	H. None of these

Questions 25 and 26:

Column A	Column B
25. ___ mtr	A. litre
26. ___ ℓ	B. likiton
	C. metre
	D. tonne
	E. None of these
	F. None of these

Now that you have completed the questionnaire, you may wish to check your answers, then place the questionnaire face-down on the table or desk.

THANK YOU!

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Appendix H

Cognitive-Learning Questionnaire Scoring Key

Page 1	Page 2	Page 3	Page 4	Page 5
D	B	B	G	E
B	D	E	E/F	E/F
C	E	E	A	A
D	C	D	C	
	A	C	E/F	
	E	D	D	
	A			

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Appendix I

Table 4:
$K\text{-}R_{21}$ for Preliminary Questionnaire

Subject	Variance Unit X	Variance Unit $(X - \bar{X})$	Variance Unit $(X - \bar{X})^2$	Subject	Variance Unit X	Variance Unit $(X - \bar{X})$	Variance Unit $(X - \bar{X})^2$
1	63	20	400	16	42	-1	1
2	60	17	289	17	42	-1	1
3	59	16	256	18	38	-5	25
4	58	15	225	19	36	-7	49
5	56	13	169	20	36	-7	49
6	56	13	169	21	35	-8	64
7	56	13	169	22	34	-9	81
8	56	13	169	23	32	-11	121
9	56	13	169	24	31	-12	144
10	56	13	169	25	30	-13	169
11	52	9	81	26	28	-15	225
12	51	8	64	27	26	-17	289
13	51	8	64	28	20	-23	529
14	51	8	64	29	15	-28	784
15	51	8	64	30	13	-30	900

Note --

Variance:
When $\Sigma X = 1290$, $\Sigma(X - \bar{X})^2 = 5952$, $N = 30$, then $S_x^2 = 5952/30 = 198.4$

K-R 21:
When $\bar{X} = 1290/30 = 43$, $n = 63$; then

$$r_{K-R} = \frac{63}{63 - 1}\left[1 - \frac{43\ (63 - 43)}{63\ (198.4)}\right]$$

$$= .95$$

This means that 95% of the total variance is associated with true scores on the test, and that 5% of the test variance is the result of error (Marshall & Hales, 1972, p. 108).

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Appendix J:

Debriefing Questionnaire

The purpose of this questionnaire is to determine how the game should be improved, so please try to answer each question. You will have ample time to answer every question. Answers may be changed by erasing. Your name is not required.

Instructions:

For each question, mark an X on the alternative that best represents your answer.

Example:

To what extent did you learn the size of metric measures while playing this game?

A	B	C	D	E
Not at all	Somewhat	~~Moderately~~ (X)	Considerably	Very considerably

1. Prior to playing this game, what was your opinion of the metric system?

A	B	C	D	E
Highly unfavorable	Somewhat unfavorable	Mixed reaction	Somewhat favorable	Highly favorable

2. To what extent did you play the game for fun?

A	B	C	D	E
Not at all	Somewhat	Moderately	Considerably	Very considerably

3. To what extent did you play to win?

A	B	C	D	E
Not at all	Somewhat	Moderately	Considerably	Very considerably

4. To what extent did you enjoy playing the game?

A	B	C	D	E
Not at all	Somewhat	Moderately	Considerably	Very considerably

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5. If you were just starting to play this game, how many cycles could you enjoy playing in one setting?

A	B	C	D	E
4 or less	5 or 6	7 or 8	9 or 10	11 or more

6. How prepared are you now to function in a metric world?

A	B	C	D	E
Not at all	Slightly	Moderately	Considerably	Totally

7. What is your opinion of the metric system now?

A	B	C	D	E
Highly unfavorable	Somewhat unfavorable	Mixed reaction	Somewhat favorable	Highly favorable

8. How many game cycles should you play to learn the size of metric measures?

A	B	C	D	E
4 or less	5 or 6	7 or 8	9 or 10	11 or more

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Appendix K:

Discussion Guide

The purpose of this discussion is to identify strengths and weaknesses in the game.

1. What is your opinion of this game?

2. What made you feel good while playing the game?

3. What made you feel uneasy during the game-playing?

4. What do you recall as the most significant thing that happened during the game-playing?

5. What relationships did you see in the information on the playing cards?

6(a). How complete were the playing instructions? (b) Explain.

7(a). Were the playing cards satisfactory? (b) Explain.

8(a). Should the Ranking Chart be changed in any way? (b) Explain.

9(a). Is the scoring system satisfactory? (b) Explain.

10. To whom would you recommend this as an enjoyable game?

11. To whom would you recommend this game as an introduction to the metric system?

12. What would you like to point out that has not already been mentioned?

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Appendix L:

Table 5: Debriefing Data-Analysis Blueprint

Category	Gaming-materials effectiveness	Affective Objectives: Enjoyment in playing	Affective Objectives: Introduction to metric via this game	Affective Objectives: Real-life relevance
Questionnaire		2 & 3 4 5	1 & 7 5 & 8 6	2 & 3
Discussion guide	1 6 7 8 9 12	1 2 & 3 4 10 12	1 2 & 3 4 5 11 12	1 2 & 3 4 10 11 12
Converter			Concerter	Converter
Game-playing observation	Game-playing observation			

Appendix M:

Game-Population Questionnaire

To help identify the most appropriate population for the game, please answer the following questions. Since it is tha game, and not you, that is being evaluated, your name is not required.

1. Check one: ____ I am less than 18 years of age.

   ____ I am 18 years of age or older.

2. Check one: ____ I know the size of metric measures such as centimetre and millilitre.

   ____ I <u>do not yet</u> know the size of these metric measures.

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Appendix N

Table 8: Affective-Objectives Data-Analysis for Tryouts

Tryout 1

Category	Source* & item	Average response over all players	Direction	Positive rating
Enjoyment in playing	Q:2 & 3	Considerably ; Somewhat	+	
	Q:4	Considerably	+	
	Q:5	9 or 10	+	
	D:1	Enjoyable	+	
	D:2 & 3	Interacting with others , Nil	+	
	D:4	Enjoyment	+	
	D:10	8 - 80 years	+	
	D:12	- - -		100%
Introduction to metric via this game	Q:1 & 7	Somewhat favorable , Somewhat unfavorable	-	
	Q:5 & 8	9 or 10 , 9 or 10	+	
	Q:6	Not at all	-	
	D:1	- - -		
	D:2 & 3	Learning a little metric , Nil	+	
	D:4	Learning a little metric	+	
	D:5	"Sets"	+	
	D:11	8 - 80 & especially those avoiding metric	+	
	D:12	Still remember some examples that were amusing	+	
	Converter	Willingly obtained & experimented with	+	78%
Real-life relevance	Q:2 & 3	Considerable , Somewhat	+	
	D:1	Excellent potential	+	
	D:2 & 3	The fun , Nil .	+	
	D:4	- - -		
	D:10	8 - 80 years	+	
	D:11	8 - 80 & especially those avoiding metric	+	
	D:12	- - -		
	Converter	Willingly obtained & experimented with	+	100%

* Q: Questionnaire
D: Discussion Guide

Continued

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Tryout 2

Category	Source & item	Average response over all players	Direction	Positive rating
Enjoyment in playing	Q:2 & 3	Moderately , Somewhat	+	
	Q:4	Very considerably	+	
	Q:5	7 or 8	+	
	D:1	Enjoyable	+	
	D:2 & 3	Socializing , Nil	+	
	D:4	Winning	+	
	D:10	12 through adult	+	
	D:12	- - -		100%
Introduction to metric via this game	Q:1 & 7	Somewhat unfavorable , Somewhat unfavorable	-	
	Q:5 & 8	7 or 8 , 11 or more	+	
	Q:6	Not at all / slightly	-	
	D:1	- - -		
	D:2 & 3	The amusing metric examples , Nil	+	
	D:4	Using Ranking Chart less, the longer we continued to play	+	
	D:5	"Sets"	+	
	D:11	Adults not learning metric via employment	+	
	D:12	- - -		
	Converter	Willingly obtained & experimented with	+	75%
Real-life relevance	Q:2 & 3	Moderately , Somewhat	+	
	D:1	Final product should be popular	+	
	D:2 & 3	Winning & fun , Nil	+	
	D:4	- - -		
	D:10	12 through adult	+	
	D:11	Adults not learning metric via employment	+	
	D:12	Would like to play an other time	+	
	Converter	Willingly obtained & experimented with	+	100%

Continued

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Tryout 3

Category	Source & item	Average response over all players	Direction	Positive rating
Enjoyment in playing	Q:2 & 3	Considerably , Somewhat	+	
	Q:4	Very considerably	+	
	Q:5	9 or 10	+	
	D:1	Good social mixer	+	
	D:2 & 3	The atmosphere , Nil	+	
	D:4	Winning	+	
	D:10	Teenagers & adults, & especially at card socials	+	
	D:12	- - -		100%
Introduction to metric via this game	Q:1 & 7	Somewhat unfavorable , Somewhat unfavorable	-	
	Q:5 & 8	9 or 10 , 11 or more	+	
	Q:6	Slightly	+	
	D:1	- - -		
	D:2 & 3	Seldom referring to the Ranking Chart during the last few games , Nil	+	
	D:4	Enjoying learning something useful	+	
	D:5	"Sets"	+	
	D:11	Senior citizens and others who shy away from metric	+	
	D:12	- - -		
	Conver-	Willingly obtained & experimented with	+	86%
Real-life relevance	Q:2 & 3	Considerably , Somewhat	+	
	D:1	Excellent	+	
	D:2 & 3	Other players , Nil	+	
	D:4	- - -		
	D:10	Teenagers & adults, & especially at card socials	+	
	D:11	Senior citizens and others who shy away from metric	+	
	D:12	Metric Commission should purchase this game for public use	+	
	Converter	Willingly obtained & experimented with	+	100%

Continued

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Tryout 4

Category	Source & item	Average response over all players	Direction	Positive rating
Enjoyment in playing	Q:2 & 3	Considerably , Somewhat	+	
	Q:4	Considerably	+	
	Q:5	9 or 10	+	
	D:1	Would enjoy playing an other time	+	
	D:2 & 3	Socializing , Nil	+	
	D:4	Enjoyment	+	
	D:10	8 through adult	+	
	D:12	- - -		100%
Introduction to metric via this game	Q:1 & 7	Mixed reaction , Somewhat favorable	+	
	Q:5 & 8	9 or 10 , 11 or more	+	
	Q:6	Slightly	+	
	D:1	- - -		
	D:2 & 3	Learning metric , Nil	+	
	D:4	Learning metric	+	
	D:5	"Sets"	+	
	D:11	Adults & perhaps school students	+	
	D:12	- - -		
	Converter	Willingly obtained & experimented with	+	100%
Real-life relevance	Q:2 & 3	Considerably , Somewhat	+	
	D:1	Excellent	+	
	D:2 & 3	Socializing , Nil	+	
	D:4	Would enjoy playing an other time	+	
	D:10	8 through adult	+	
	D:11	Adults & perhaps school students	+	
	D:12	Excellent for card socials	+	
	Convertor	Willingly obtained & experimented with	+	100%

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Appendix O

Cognitive-Learning Questionnaire Introduction

The purpose of this questionnaire is to determine how effective the game is. Since it is the game, and not you, that is being evaluated, your name is not required. Your answers will be seen by no one but the administrator and will be used only for the purpose of improving the game. Your score will be the number of questions answered correctly. Try to answer each question and to make your score as high as possible. There is no penalty for guessing. You may change answers by erasing. You will have ample time to complete the questionnaire.

To help identify the most appropriate population for the game, please answer the following questions:

1. I am ____ years of age.
2. My annual salary is approximately ____ thousand dollars.

Now, fold this sheet only so that your answers remain confidential. But do NOT look at the questionnaire until asked to do so.

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Appendix P:

Cognitive-Learning Questionnaire Introduction

The purpose of this questionnaire is to determine how effective each question is. Since it is the questionnaire, and not you, that is being evaluated, your name is not required. Your answers will be seen by no one but the administrator and will be used only for the purpose of improving the questionnaire. Your score will be the number of questions answered correctly. Try to answer each question and to make your score as high as possible. There is no penalty for guessing. You may change answers by erasing. You will have ample time to complete the questionnaire.

To help identify the most appropriate population for this questionnaire, please answer the following questions:

1. I am ____ years of age.
2. My annual salary is approximately ____ thousand dollars.

Now, fold this sheet only so that your answers remain confidential. But do NOT look at the questionnaire until asked to do so.

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Appendix Q

Table: 10 K-R_{21} for Final Version of Questionnaire

Subject	Variance Unit			Subject	Variance Unit		
	X	$(X - \bar{X})$	$(X - \bar{X})^2$		X	$(X - \bar{X})$	$(X - \bar{X})^2$
1	26	7.8	50.84	11	19	.8	.64
2	24	5.8	33.64	12	19	.8	.64
3	24	5.8	33.64	13	18	-.2	.04
4	24	5.8	33.64	14	18	-.2	.04
5	23	4.8	23.04	15	18	-.2	.04
6	23	4.8	23.04	16	12	-6.2	38.44
7	23	4.8	23.04	17	8	-10.2	104.04
8	22	3.8	14.44	18	8	-10.2	104.04
9	22	3.8	14.44	19	7	-11.2	125.44
10	20	1.8	3.20	20	6	-12.2	148.84

Note --

Variance:

When $\Sigma X = 364$, $\Sigma(X - \bar{X})^2 = 775.16$, $N = 20$;

then $Sx^2 = 775.16 / 20 = 38.76$

K-R_{21}:

When $\bar{X} = 364 / 20 = 18.2$, $n = 26$,

then $r_{K-R} = 26 / 26 - 1 \left\{ 1 - \left[18.2\ (26 - 18.2) / 26\ (38.76) \right] \right\}$

$= .99$

This means that 99% of the total variance is associated with true scores on the test, and that 1% is the result of error (Marshall & Hales, 1972, p. 108).

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Appendix R

Table: 12

Multiple Comparisons Employing Scheffé Procedure

Variance estimate (S_w2):

A		B		C	
x	x^2	x	x^2	x	x^2
24	576	26	676	23	529
24	576	24	576	22	484
23	529	23	529	19	361
19	361	22	484	18	324
18	324	20	400	18	324
				12	144
				8	64
				8	64
				7	49
				6	36

				Total
No. of scores in column	5	5	10	---
Sum of scores in column	108	115	141	---
Sum of squares of each score in column	2366	2665	2379	7410
Divide square of sum of scores in column by no. of scores in column	2332.8	2645	1988.1	6965.9

Sum of squares	Degrees of freedom	Variance estimate
7410 - 6965.9 = 444.1	20 - 3 - 17	444.1 / 17 = 26.12

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Comparisons:

(A + B), C:

Mean (A + B) = (108 + 115) / 10 = 22.3

$$F = \frac{(22.3 - 14.1)^2}{26.12 / 10 + 26.12 / 10}$$

$= 10.97$

A, C:

$$F = \frac{(21.6 - 14.1)^2}{26.12 / 5 + 26.12 / 10}$$

$= 7.76$

B, C:

$$F = \frac{(23 - 14.1)^2}{26.12 / 5 + 26.12 / 10}$$

$= 10.16$

B, A:

$$F = \frac{(23 - 21.6)^2}{26.12 / 5 + 26.12 / 5}$$

$= 1.88$

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Appendix S

Table 14: Affective Data-Analysis for Field Trial

Category	Source* & item	Average response over all players	Direction	Positive rating
Enjoyment in playing	Q:2 & 3	Considerably , Moderately	+	
	Q:4	Considerably	+	
	Q:5	9 or 10	+	
	D:1	Enjoyable	+	
	D:2 & 3	Fun , Nil	+	
	D:4	Enjoyment	+	
	D:10	Teenagers & adults	+	
	D:12	- - -		100%
Introduction to metric via this game	Q:1 & 7	Mixed reaction , Somewhat favorable	+	
	Q:5 & 8	9 or 10 , 11 or more	+	
	Q:6	Somewhat	+	
	D:1	- - -		
	D:2 & 3	Learning common metric measures	+	
	D:4	How little use was made of Ranking Chart in the last few games , Nil	+	
	D:5	"Sets"	+	
	D:11	Teenagers & adults	+	
	D:12	Excellent family game	+	
	Converter	Willingly obtained & experimented with	+	100%
Real-life relevance	Q:2 & 3	Considerably , Moderately	+	
	D:1	Excellent with suggested improvements	+	
	D:2 & 3	Socializing & winning , Nil	+	
	D:4	Socializing	+	
	D:10	Teenagers & adults	+	
	D:11	Teenagers & adults	+	
	D:12	Excellent family game	+	
	Converter	Willingly obtained & experimented with	+	100%

* Questionnaire
Discussion Guide

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