A Model of Technology Capable of Generating Research Questions

Andrew S. Gibbons
Brigham Young University

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Several frameworks have been suggested for the generation and prioritization of research questions in the field of instructional technology. These include learning theory, philosophy, systems theory, and instructional theory. A model of technological activity that distinguishes technological from scientific inquiry can also be used to generate research topics, with the advantage that the knowledge produced is in a form more readily usable by the designer. Such a model is illustrated in Figure 1.

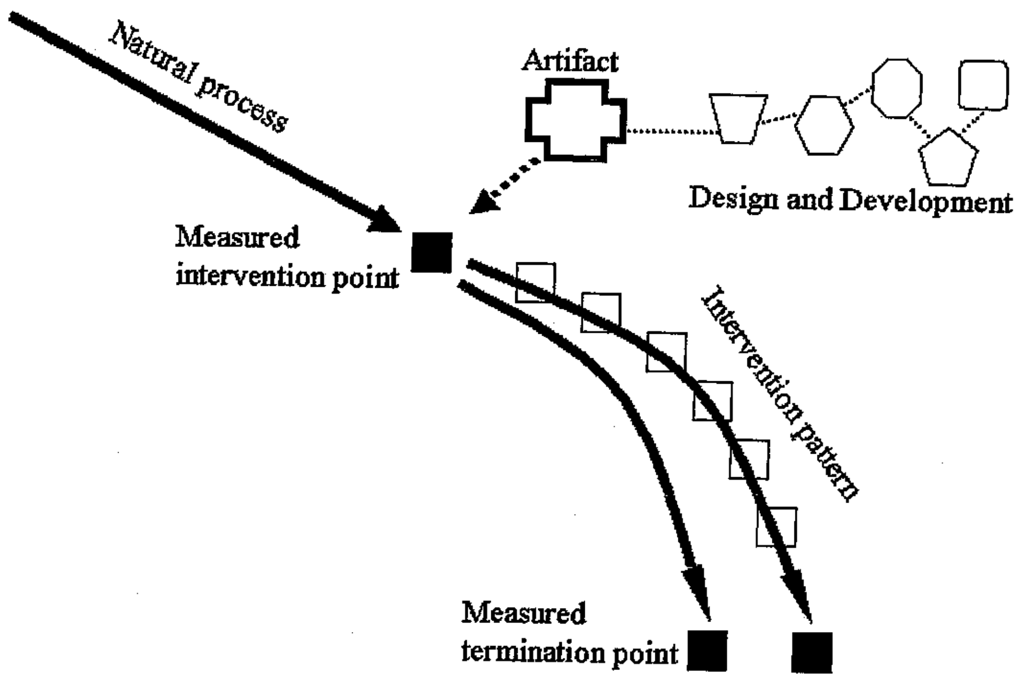

Figure 1. A model of technological activity capable of generating research questions for instructional technology.

Figure 1 represents ongoing natural processes with a slanted line entering from the left. These processes continue independently of human volition. Left undisturbed the processes propagate energy and information along natural paths studied by scientists, who attempt to describe and explain them and the forces that drive them (Klir, 1969; Klir, 1985). When humans intentionally intervene in these processes in order to achieve a particular outcome, the path of events may be deflected, which is represented by the arcs moving downward to the right in Figure 1. For the purposes of this paper, the point of intervention and the course of the resulting events and further interventions constitute the appropriate region for technological study (Gibbons, 2003; Gibbons & Bunderson, 2004). In this region, though events are driven forward by the same natural processes, there is an added dimension to be studied consisting of theories and principles of planned actions and the deliberate structuring of forces and information. This is the region of designing and design execution; it will be treated in this writing as the region of technological study.

The elements of a planned intervention illustrated in the model in Figure 1 suggest categories for research and priorities among them. In some cases, the categories described below represent a combination of more traditional research categories or a change of perspective with respect to a traditional research topic. In some cases, the categories below represent new categories for technological study that correspond to those used in other design fields. The list of research topics below is derived from the narrative sequence of Figure 1. Its categories are suggested in several sources (including: Simon, 1999; Klir, 1969; Vincenti, 1990; Alexander, 1964; Schön, 1987; Layton, 1992; Bucciarelli, 1994; and others).

Measurement

The intervention point in a deliberate application of technology is a *measured* intervention point. Subsequent intervention points or points of modification of the intervention are also measured, as are the end points at which intervention is terminated. Realizing that decisions during intervention are based on multiple, diverse criteria, this perspective adds breadth to traditional studies of measurement, placing a premium on measurements: (1) that are continuous or frequent and therefore repeatable, (2) that report the performance and response of many aspects of the system influenced by the intervention, (3) that are highly interpreted in terms of motives and degrees of engagement, and therefore (4) that require triangulation of multiple measures under sometimes severe timing constraints. (Bunderson et al, 1989) These aspects of measurement depart in an applied direction from traditional measurement research and emphasize application of measurement to influence an ongoing process. The participation of measurement in every aspect of an intervention also gives priority to research on measurement-related topics such as subject-matter analysis, event structure analysis, mental structure analysis, and other topics that provide primitive categories to which intervention-related measurements can be related (see for instance Bunderson & Wiley, in preparation).

Intervention patterns

Figure 1 illustrates the possibility of multiple, measured intervention points. These may represent points at which minor adjustments are made in intervention values or points that mark a major departure in the intervention such as changes of the intervention artifact, the intervention process, or the timing of the intervention. A minor adjustment may involve an increase or decrease in the amount of a medication; a major adjustment may involve the addition of chemicals to a steel melt, followed by molding, quenching, forging, and/or drawing to determine the crystalline structure of the steel. (Misa, 1995). Intervention patterns can be described with reference to stages of progress toward a targeted outcome; each stage may be characterized in terms of measures on the same or on different sets of parameters (e.g., temperature of a melt, chemical composition of a melt, compression of an ingot by forging, rate of drawing, etc.). Progress toward instructional goals can similarly be characterized in terms of intermediate steps at both macro-and micro-levels. Research on patterns of intervention places emphasis on the description of intermediate stages rather than on single-event outcomes and supports an innovative view of the instructional goal and of methods to guide instructional goal-setting. In particular, the notion of single, static goals gives way to the view of dynamic scoping and goal trajectories which cause us to see instruction as a process that can possess and gain momentum. Measurement in this conception is interested in construction of performance curves, trend lines, effect curves, and effect surfaces. Research in this area must also include the computation of probabilities of success of competing possible interventions from a given intermediate point. This re-characterizes instructional strategies as dynamic computations rather than as static formulas or templates and favors the participation of learners in strategic decisions.

Artifact types and structures

Interventions are made by the means of artifacts (see Figure 1). Artifacts are structurings of information and/or force (energy) that work either through injection or catalysis to influence the path of natural processes—in our case, learning processes. A traditional view of instruction as the direct transfer of information structures to the learner's mind has given way to more complex views in which information and forces are made available to the learner as raw materials, to which the learner may respond by constructing understanding, feelings, or performance capability, often based on a multiplicity of inputs. In both cases, the artifacts: (1) the instructional materials, and (2) the processes of instructional events can be seen as attempts to structure information and the awaken motivation, engagement, interest, desire, and other forces that impel the learner forward toward acts of choice that lead to learning. In this process, learners either absorb information and forces or transform them into new organizations. This places emphasis on the study of the transforming processes of learner and the catalysis performed by a full range of time-space, and information structurings the designer can possibly conceive. It subtly shifts emphasis away from study of traditional categories of artifacts, events, and forms and toward new categories based on event structures, information structures, affect and conation states, and an ongoing negotiation of goals and resources in collaboration with learner. This implies the study of instruction as a conversational process in which the learner becomes a participant in telling of the subject-matter story and ultimately the managers of their own learning processes (Gibbons, 2004).

Artifact design and fabrication processes and tools

The traditional approach to an artifact design problem has been to divide the problem by decomposition into sub-problems for solution. Over several years, instructional designers have created a standard approach that involves decomposition in terms of design processes, normally referred to as ISD, ADDIE, or a "design model".

An alternative view which may yield new directions for research divides design problems into layers and sub-layers representing the *functional partitioning of the designed product* rather than of the design process. In this view, artifact structure is considered in terms of a set of integrated structures operating at different abstract layers, each supporting a particular function our injecting a particular pattern or behavior into the artifact. Single instructional events and material artifacts are thus seen as multiple layers of structures bound together to fill an overall purpose.

This alternative to the subdivision of design problems is consonant with descriptions of design-making in other fields. It also focuses attention on families of design languages used for designing within different layers. Though attention to design languages has led to progress in other design fields, they are often not noticed in instructional design (Gibbons & Brewer, 2004). Recognition of these languages has many implications:

- Notation systems. Abstract languages are most often represented in a public form by the means of notation systems that aid and are aided by development of the language itself. In many advanced design fields notation systems and languages have been at the root of rapid advances in design technology, since they allow symbolic manipulation of the abstract ideas involved in design problem solutions (Waters & Gibbons, 2004). Both languages and notation systems are valuable study topics because they lead to further elucidation of the design activity itself (see Simon, 1999, p. 137).
- Participatory designs. Public symbolic notation of abstract design language concepts means that multiple designers can more readily share in designing and design reviews, that designs can become more complex and nuanced, and that design patterns can be lifted or abstracted for future use. Experience in many design fields (Booch, Jacobson, & Rumbaugh, 1998) has shown that designs framed in terms of layers (or "views") usually require multiple design expressions (graphs, views) to create a complete design. Public symbolic notation suggests the possibility of the evaluation of designs within shared work spaces. (Fischer & Sullivan, n.d.) This provides additional means for studying the social dimension of design by groups and teams and how not only designs but new design languages emerge under working conditions.
- Alignment with tool structures. Design languages existing at different layers of a design imply multiple kinds of structural figures ("building blocks") that are involved in design creation. A rich field of study maybe found in the manner of alignment of these abstract sets with the building blocks supplied by software development tools. It is likely that study in this area could result in new tool types and configurations (Gibbons & Fairweather, 2000).
- Computational leveraging of the language principle. Existence of languages for expressing designs implies that designs may be generated and manipulated as rule-bound expressions of languages. This principle has been a major factor in rapid advances made in other technology fields over the last 30 years. Generation can include real-time generation of instructional experiences from primitive

elements, or real-time assembly of experiences from existing, reusable elements assembled from distant sources. Research on the relationship of design languages and layer designs to these outcomes may be fruitful.

- Re-examination of principles of design order. This alternative view of layers and languages challenges us to reexamine the design process itself, looking for a characterization of the process that can be tailored more readily to the needs of individual design projects. Artifact design can be seen as a sequence of decisions that places successive dimensions or constrains on abstract structures (Gross, Ervin, Anderson, & Fleisher, 1987; Layton, 1992). If so, each design decision can be rationalized, ordered, and disciplined by earlier decisions. This presents a new point of view for describing the design process and the order of design decisions.

Conclusion

My purpose has been to suggest that a model of technological intervention can be used to derive worthwhile research topics and that those topics place a new perspective on traditional research categories. The list of categories presented has not attempted to be exhaustive, but it does identify new categories for research topics and imply new perspectives and priorities.

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