Rapid Prototyping Methodology in Action: A Developmental Study

□ Toni Stokes Jones
Rita C. Richey

This study investigated the use of rapid prototyping methodologies in two projects conducted in a natural work setting. It sought to determine the nature of its use by designers and customers and the extent to which its use enhances traditional instructional design (ID). With respect to describing rapid prototyping use, the results pertain to designer tasks performed, the concurrent processing of those tasks, and customer involvement. With respect to describing the enhancements facilitated by rapid prototyping, the results pertain to design and development cycle-time reduction, product quality, and customer and designer satisfaction. In general, the two projects studied show ID efforts that created products that were usable for a conveniently long period of time without revision; delivered in a shorter period of time than would have been expected using traditional techniques; and received by satisfied customers who had been involved throughout their development. In other words, the rapid prototyping methods lived up to their promised benefits.

□ Instructional designers are frequently confronted with demands not only to generate high quality products, but also simultaneously to reduce design and development time. One solution to this dilemma is the use of rapid prototyping (RP) methodologies. RP methodologies should reduce production time because: (a) using working models of the final product early in a project tends to eliminate time-consuming revisions later on, and (b) design tasks are completed concurrently, rather than sequentially, throughout the project. RP methodologies will satisfy customers because they are involved in an extensive formative evaluation of the actual product throughout its design and development. In essence, the thrust of this research was to test these assumptions by studying the use of RP in a natural setting and to suggest a detailed RP design model that would be useful in other environments.

THE NATURE OF RP

RP involves the development of a working model of an instructional product that is used early in a project to assist in the analysis, design, development, and evaluation of an instructional innovation. Many view RP methods essentially as a type of formative evaluation that can effectively be used early and repeatedly throughout a project (Tessmer, 1994). For others, however, it involves more profound changes in the traditional approaches to design.

RP typically has been used in software engineering, but recently others, including instructional designers, have devised ways to apply these methodologies to their work. For example, RP methods have been used in instructional design (ID) to develop:

- Instruction to simulate a university's registration process (Haugen & Nedwek, 1988)
- Educational software for secondary education programs (Graells, 1993)
- A research tool to assist in developing instructional strategies and approaches (Muraida & Spector, 1993)
- User documentation (Berry, Mobley & Turk, 1994)
- Instructional videos (Appleman, Pugh & Slantz, 1995)
- An electronic performance support system to support school teachers in the use of alternative assessments (Law, Okey & Carter, 1995)
- Courseware production (Yang, Moore, & Burton, 1995)
- A four-day instructor-led training school to give the pilot-course learners a sound learning experience, and to generate feedback to be integrated into the next version of the course (Lange & Shanahan, 1996)

While RP has been used more often with the design of computer-based products, it is also a vehicle for designing paper-based products (Berry et al., 1994). A closer examination of these design and development projects shows that RP is used in a variety of ways. This literature has been reviewed to identify the kinds of prototypes used, the design models employed, evidence of cycle-time reduction, and evidence of customer involvement.

What Is a Design Prototype?

The purpose of RP methods is to realize the conceptual structure of the final product while not incurring the expense of the full product development cycle (Jones, Li, & Merrill, 1992), but in practice these prototypes vary depending on project needs. Basically, prototypes are either workable models of the final product, or simply shells that demonstrate the projected appearance of the product. Formats vary depending on the medium and use of the final product. In some instances, the prototype is discarded after use, while in others it evolves into additional prototypes and ultimately into the final product (Hix & Hartson, 1993; Moonen, 1996; Reilly, 1996).

Various prototype formats identified in the literature are summarized in Table 1. Scope or visual prototypes represent the "look and feel" of the anticipated product, but they have little, if any, functionality. While they may focus on a specific detail that is important to the final product, such prototypes are usually discarded. Executable prototypes, on the other hand, are useable and typically evolve into the final product after evaluation.

All prototypes enable designers to determine the best product format and the most effective instructional strategies while acknowledging, rather than minimizing, the complexity of actual instructional situations (Tripp & Bichelmeyer, 1990). It is not unusual to employ multiple prototype formats in a given project (Gustafson & Branch, 1997; Berry et al., 1994; Hix & Hartson, 1993; Luqi, 1989). Often the initial prototype emphasizes only the visual aspects of the final product because these are less costly and less demanding to build. After overall format decisions have been made, an executable prototype may be constructed to determine the product's usability. Table 2 shows the various kinds of prototypes that have been used in a single project.

What Procedures Embody Rapid Prototyping?

Tripp and Bichelmeyer's 1990 model served as an early introduction to designers of RP possibilities. Their model is very general; it shows the relationships between traditional design phases and the use of prototypes: assess needs and analyze content; set objectives; construct prototype; utilize prototype; install and maintain system. One example of a more recent RP model in the literature is Yang's model for use in developing computer-based courseware (Yang et al., 1995). This is a three-dimensional model focusing on three traditional stages: (a) analysis, (b) development, and (c) evaluation. The model is best used

Table 1 ☐ A Description of Alternative Prototype Formats

Scope/Visual Prototypes	*Executable Prototypes*
Alpha Prototype—typically first version of the prototype that illustrates format, navigation, content, and graphics. May have some user and computer interactions. Also known as a Working Prototype. (Appleman, et al., 1995; Law, et al., 1995; Yang, 1995)	*Beta Prototype*—essentially a finished product that is ready for pilot test or research; has complete functionality (syntactically complete). Also known as Pilot Prototype. (Appleman, et al, 1995; Yang, 1995)
Documentation Prototype—models the completed user documentation [paper or online]. Illustrates format, graphics, and presentation. (Berry, et al., 1994)	*Functional Prototype*—demonstrates user and computer interactions. May be syntactically complete or incomplete. Also known as Technical Prototype. (Gray & Black, 1994)
Generic Template Prototype—used across multiple units to illustrate content; instructional strategies, media, and setting; and measurement tools. (Yang, 1995)	*Pilot Prototype*—Contains instructor materials and content and short module content for the participants of a pilot/pre-implementation training session. Also known as Beta Prototype. (Lange & Shanahan, 1996)
User-Interface Prototype—illustrates navigation and flow without complete functionality (syntactically incomplete). Also known as Mockup Prototype. (Gray & Black, 1994; Hix & Hartson, 1993)	*Rough Cut Prototype*—illustrates labeling conventions, sequencing, clarity of the message, and pacing in a videotape. (Appleman, et al., 1995)
Mockup Prototype—illustrates navigation and flow without complete functionality (syntactically incomplete). Also known as User-Interface Prototype (Gray & Black, 1994; Hix & Hartson, 1993)	*Rough Sequence Prototype*—illustrates clarity of images sequenced together in videotape. (Appleman, et al., 1995).
	Technical Prototype—typically illustrates usability of the prototyping tools and processes when developing computer-based products. Also known as Functional Prototype.

in conjunction with a software-engineering-based template for managing production activities. It was tested with the production of postsecondary-science instructional materials. It appears that neither of these models has been used on a regular basis for either nonprofit or commercial purposes.

The literature also includes other RP models that have evolved from actual demonstration projects. While there is no consistent set of procedures, they do tend generally to conform to a traditional ID cluster of phases—Analysis, Design, Development, Implementation and Evaluation (ADDIE). Those tasks pertaining to prototype construction and use, however, tend to merge design and development activities. Consequently, we have embedded this blended phase into the generalized ADDIE model so that we can summarize the procedural design models of key RP projects described in the literature. Table 3 compares the procedures of those projects described in sufficient detail to lend themselves to such analysis. These models tend to consistently emphasize predesign analysis, design and development. They de-emphasize summative evaluation, but stress formative evaluation. This is consistent with the Tessmer (1994) observation previously noted.

Unlike traditional ID models, RP uses parallel processing of the various design and devel-

Table 2 ☐ Prototype Formats used in RP Projects

Rapid Prototyping Projects & Products	*Appleman, Pugh & Slantz* Instructional Video (1995)	*Berry, Mobley & Turk* User Documentation (1994)	*Graells* Computer-Based Training (1993)	*Haugen & Nedwek* Student Information System (1988)
Scope/Visual Prototype				
Alpha Prototype	×		×	
Iterative Documentation Prototype		×		
Generic Template Prototype				
Executable Prototype				
Beta Prototype	×		×	
Pilot Prototype				
Rough Sequence Prototype	×			
Rough Cut Prototype	×			
Multiple Prototypes Cited; Format Unidentified		×		×

Table continues

opment tasks. The activities are intertwined (Goodrum, Dorsey & Schwen, 1993). As such, RP methods encourage iterative design, based on structured early feedback. Although it is difficult to isolate this phenomenon in the models as described, Collis and de Boer (1998) do isolate parallel activities in their RP process. Their project involved redesigning World Wide Web-based courses and instructional methods and had three parallel activities. The first of the three parallel activities included weekly hands-on sessions of the faculty with the first prototypes. The second of the parallel activities involved working group sessions to develop a new didactics along with "the ongoing development of the course WWW sites, evolving from the first to the second prototypes" (p. 118). The third of the parallel activities involved sessions to demonstrate the new didactics and the use of technology through a simulated class called the Wednesday class. Collis and de Boer utilized their RP process to increase communication among the faculty and instructional designers and to develop other versions of the prototype.

RP and Cycle-Time Reduction

The primary rationale for using RP methods in a design project is that they are presumed to reduce the time needed to complete a design and development project. However, none of the RP projects described in the literature provided evidence of cycle-time reduction, in spite of the widespread belief that it does occur in ID settings. For example, Arthur (1992) asserts that prototypes may be capable of reducing design and development cycle time by a factor of four or more when designing and developing information systems software. Cycle-time reduction is presupposed essentially because prototype evaluation ensures that required revisions to the product, process, or project outcomes may occur early in the project. It also occurs because of the increased use of computer-based design and

Table 2 ☐ *Continued*

Rapid Prototyping Projects & Products	*Lange & Shanahan* *Instructor-Led Training (1996)*	*Law, Okey, & Carter* *EPSS (1995)*	*Muraida & Spector* *Research Tool (1993)*	*Yang* *CBT (1995)*
Scope/Visual Prototype				
Alpha Prototype		×	×	×
Iterative Documentation Prototype				
Generic Template Prototype				×
Executable Prototype				
Beta Prototype				×
Pilot Prototype	×			
Rough Sequence Prototype				
Rough Cut Prototype				
Multiple Prototypes Cited; Format Unidentified	×			

development tools that typically facilitate prototype construction (Haugen & Nedwek, 1988; Jones et al., 1992; Tripp & Bichelmeyer, 1990). Finally, cycle-time reduction is assumed because there is the expectation of concurrent design activities through the use of design teams.

RP and Customer Involvement

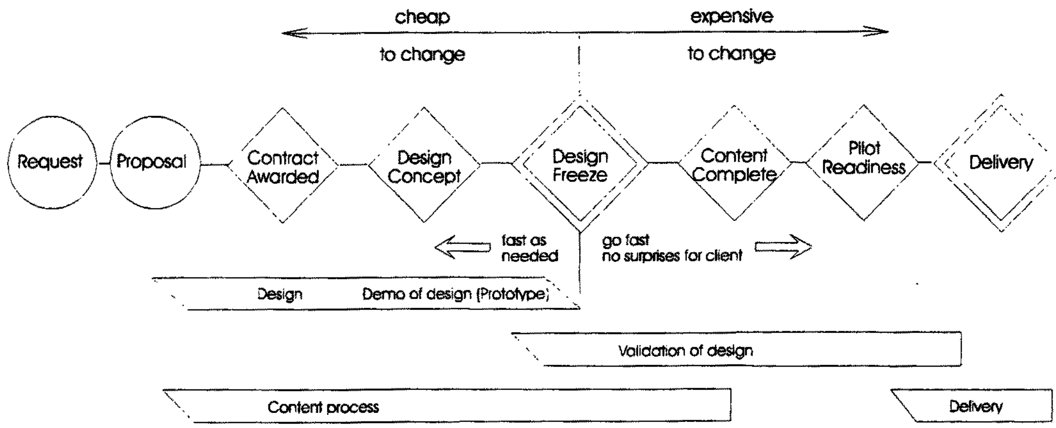
The use of prototypes early in the development process stands in contrast to many development projects where the customer does not see the product until it is nearly completed. The cost of making changes to a nearly finished project is often prohibitive, which results in a limited role for the customer. Customer involvement with RP is at a higher level because of the review of early prototypes that are more easily modified based on customer input. The prototype encourages communication between everyone concerned with the effort. Consequently, the working relationships and the interactions among customers and design teams are important aspects of the RP approach (Gray & Black, 1994).

Customers' roles are multi-faceted. They may serve as subject-matter experts, end-users, or purchasers of the product. As subject-matter experts, customers may assist in content identification throughout the project (Gray & Black, 1994). As end-users, customers react to the prototype to provide feedback regarding the design, the instructional activities and user interface (Appleman et al., 1995; Gustafson & Branch, 1997; Lange & Shanahan, 1996; Law et al., 1995). It is anticipated that, as financing agents, customers will express their satisfaction with the product and the processes used. Tripp and Bichelmeyer (1990), when citing the advantages of RP methods, noted that clients typically "don't know their requirements until they see them implemented" (p. 42). The ability to see a product in as near-deliverable format as possible is invaluable in helping nondesigners anticipate a final product and react so that design teams may make needed modifications (Burton & Aversa, 1979). Still, there has been little research that has focused on the customer's role in RP.

Table 3 ☐ Rapid Prototyping Procedures

Rapid Prototyping Models or Projects	*Appleman Pugh & Slantz*	*Graells*	*Lange & Shanahan*	*Law, Okey, & Carter*	*Tripp & Bichelmeyer*	*Yang*
Product	*Instructional Video (1995)*	*Computer-Based Training (1993)*	*Instructor-Led Training (1996)*	*EPSS (1995)*	*not specified (1990)*	*CBT (1995)*
Analysis						
Generate Idea & Initial Design Meeting		×	×			×
Assess Organizational & Instructional Needs		×	×	×	×	×
Analyze Content		×	×			×
Identify Audience		×	×			×
Define Goals & Objectives		×	×		×	×
Design						
Identify/Develop Instructional Strategies		×	×			×
Select/Develop Media		×	×			×
Write Design Specs		×	×			
Design/Development						
Identify Prototype Content	×	×	×			×
Construct Prototype	×	×	×	×	×	×
Use & Evaluate Prototype	×	×		×	×	×
Refine Prototype	×	×		×		×
Confirm Prototype	×	×		×		×
Development						
Complete Development		×			×	×
Conduct Pilot			×			×
Development			×			×
Implement						
Deliver Product			×			×
Install & Maintain System		×			×	×
Evaluate						
Summative Evaluation						×

Figure 1 ☐ The Target Firm's Instructional Systems Design/Rapid Prototyping Model



METHOD

This was a developmental research project (Richey, 1997; Richey & Nelson, 1996) using qualitative methods and a natural work environment. It was initiated because of the paucity of research on RP methodologies, especially studies that sought to validate RP methods in action. One particular approach to RP was studied here during its use in two separate and diverse ID projects. More specifically, this study addressed the following key questions:

1. What are the precise applications of RP methodology in a variety of design situations? Is there evidence that the designer-developers applied the RP model in their work? If so, how did they do this? What do the customers do? What is the nature of the concurrent completion of design tasks?
2. To what extent does RP methodology enhance the process of instructional systems design? Does it reduce design and development cycle time? Does it improve the quality of the instructional product? Are the customers and designers more satisfied?

The Setting of the Study

The research was conducted at an instructional design and development firm operating in Metropolitan Detroit. This firm consists of 14 full-time employees and works with approximately 28 contractors on an as-needed basis. While the firm conducts business worldwide and has a secondary office in Denver, CO, the majority of its business is concentrated in the Detroit area, in training applications in automotive manufacturing. All of its work involves custom design. The firm's projects include designing, developing, implementing and evaluating instructor-led training, computer-based training, Internet-intranet certification testing, and hypermedia software. In addition, the firm conducts needs analyses and comprehensive evaluation projects including assessments of performance improvement and organizational impact. The projects last from four months to three years.

The Target RP Model

In 1991 the firm adopted an ID model based on a fast cycle-time approach to its work. This RP model complements the traditional systems approach to ID. Since then, the firm has used it for the design of paper-based instructional materials, as well as computer-based materials. The model is shown in Figure 1.

This graphic is used for marketing and communications purposes as well as for project management as demonstrated by the references to the costs of change. The approach has three major milestones: (a) Kickoff; (b) Design Freeze; and (c) Pilot Ready. The model in Figure 1 illustrates milestones (b) and (c). There is an expanded version that includes more detailed recommended tasks; tasks that are often completed with the customer and done concurrently. The Kickoff is a meeting that occurs immediately after the contract is awarded and includes the customer team and the ID team. Here the groups identify roles and responsibilities, and review meetings, work schedules and other business matters. The Design Freeze milestone marks full agreement between the customer and design teams on product format, content, and instructional strategies. Further changes will be limited to wording and minor graphic changes; structure and treatment changes will be considered above and beyond the contract. This milestone triggers rapid completion of the product. The third milestone, Pilot Ready, indicates that the product is ready to be pilot tested with actual users. Such testing (with a beta prototype) may show the need for minor revisions pertaining to areas such as timing or flow of activities. After revisions are made, the final product is delivered to the customer.

Concurrent processing takes place throughout the process. For example, the rectangular boxes in Figure 1 indicate that as early as the proposal writing phase, content is being scrutinized and ID is being considered. Once the contract has been awarded the content review and design considerations intensify and are manifested in the design concept memo and prototype. The firm's more detailed process descriptions identify 14 key tasks that guide the ID teams. These tasks follow. We have clustered them into the modified traditional design clusters as previously presented in Table 3.

Analysis

1. Identify audience
2. Identify instructional need
3. Identify content to the task level

Design

4. Identify instructional strategy
5. Write design memo and obtain approval
6. Write general content outline

Design and Development

7. Identify prototype content
8. Build prototype
9. Review prototype
10. Freeze design

Development

11. Complete development
12. Conduct pilot
13. Revise product
14. Deliver product

Projects and Participants

Instructional designers. This research addresses the activities of two instructional designers on two projects. The designers were selected because they had used the target RP model and had been in the field at least 5 years. Designer 1, a 44-year-old female, senior designer with 8 years of experience and a Ph.D. in Instructional Technology, worked on Project 1. Designer 2 was a 47-year-old male, senior designer with 14 years of work experience, currently pursuing a Ph.D. in Instructional Technology.

Customers. The activities and reactions of one customer from the two projects will be discussed here. The target firm's president-principal, based on his role in the project that employed RP, identified this customer. He was associated with an automotive manufacturing firm and his role on the project was that of subject-matter expert. As subject-matter expert, he requested the design services and had the responsibility for confirming that the training products were appropriate for the intended audience and for user evaluation of the prototypes. Throughout Project 1, he was in continual communication with the assigned design team. Because of illness, Project 2 did not have customer participation; consequently, Project 1 was the only project with customer participation.

Projects. The two projects in this research involved designing and developing instructional materials used in very different situations using the RP methodology. The projects varied in terms of size, product, and industry. Their products included both paper-based and electronic-based instructional materials. Project 1 was geared to the needs of the automotive industry. The resulting program was a one-day instructor-led class with a matching online tutorial. The products were an instructor's guide, a participants' guide, the tutorial, and a tutorial user's guide. The prototype for Project 1 was an interface design prototype of the instructor's and participants' guides that evolved into the final product. There was no prototype for the online tutorial.

Project 2 involved the development of a one-day instructor-led training program delivered via electronic media in the health care industry. The products were an instructor's guide and a participants' guide. The prototype for Project 2 was an interface design prototype representing page layout, course flow and activities of the final materials. It was not discarded because it was built using the same software and hardware used in the development of the final product.

Data Collection and Instrumentation

Instructional designer data collection. The same three data collection procedures and instruments were used with both projects in this study: (a) survey or task log, (b) personal interview, and (c) review of extant data. Each designer was given a task log to complete. The purpose of the log was to determine what tasks had been completed on a project using the RP methodology. Using the log, each designer described how the 14 prescribed tasks were completed, identified concurrent tasks and recorded task completion time. To help recall the prototyping process, the log provided definitions of phases of the design and development cycle. For example, the log identified the design process, which includes a design memo, prototype design and review, and creation of a general content outline. (The log was field-tested by a former designer from the firm who was experienced in the particular RP methodology being studied.) As part of the task of completing the log, designers were asked to review extant data pertaining to the target projects to help them recall the details of the projects. Such data included the original project proposals, time sheets, design memos, prototype design specifications, project-related memos, and the final products.

Following the receipt of the logs, an audiotaped interview was conducted with each designer, using a structured-interview schedule. The interview served to clarify log entries, and to determine the impact of the RP methodology on the design and development process and on product quality. Each interview took approximately one hour. The following nine questions were used as the initial stimulus for discussion:

1. Did you explain the RP process to the customer?
2. What was his or her reaction to the process?
3. Now that you have used RP, what is your feeling about it?
4. What, if any, negative feelings or regrets do you have about using RP?
5. What, if any, positive feelings do you have about using RP?
6. How complete were the revisions to the prototype?
7. How complete were the revisions to the final product after the pilot?
8. How closely does the final product resemble the prototype?
9. What, if anything, would you do or have you done differently when using RP since this project? Why?

Other questions were asked to follow up particular responses.

Customer-project data collection. A telephone interview lasting approximately 45 min was used to collect the customer data. The interview was structured around an open-ended questionnaire with prompts to aid recall of the project. It was audio taped with the respondent's permission. Customers were asked to agree or disagree and explain their perceptions of product quality, level of customer involvement, cycle time, and customer satisfaction and product usability.

Although the target firm's marketing director, bookkeeper and two principals were not customers and did not complete task logs or participate in follow-up interviews, they did provide additional background information on the projects via e-mail. They responded to questions concerning product use, product updating and customer satisfaction with the final products.

Data Analysis

The data gathered related to the nature of the RP process itself, attitudes toward RP and the final products, cycle time, and customer involvement. These data were derived from transcribed, audiotaped interviews and the logs. The data were coded by topic. The customer data were coded by customer attitude toward RP; customer satisfaction with the product, process and product usability; cycle-time reduction-increase; customer involvement-tasks; and comparison with other models. The designer data were coded by designer attitude toward RP; customer satisfaction with the product, process, and product usability; cycle-time reduction-increase; customer involvement; comparison with other models; product quality; designer tasks; concurrent processing; and time to complete tasks.

An objective third party reviewed the coding decisions to verify the codes and interpretations given to her. Coding disagreements were discussed and, based on the collective opinion of the coder and the reviewer, appropriate changes made. Data were then sorted and analyzed using Nud*ist qualitative software to facilitate the description of the manner in which RP methodologies are actually employed, and the extent to which these methods enhance the traditional ID process.

RESULTS

Using Rapid Prototyping Methodologies

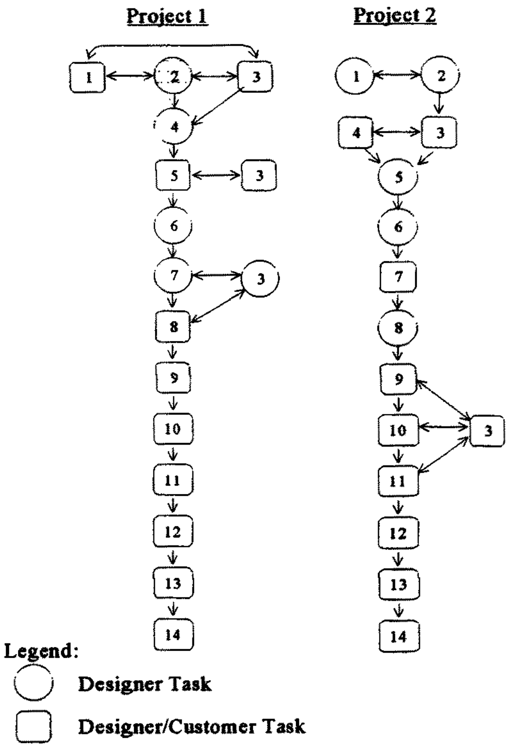
The first research question pertains to how RP methodologies were actually used, with particular attention given to the nature of designer tasks, customer involvement, and concurrent completion of design tasks.

Designer and customer tasks. The target firm typically describes its RP model in terms of 14 tasks. These tasks are listed in Table 4, along with indications of which tasks were performed by designers and which by customers in each project. The results suggest that, in general, designers did follow the RP model in their work. In Project 1, the designer performed each specified

Table 4 ☐ Rapid Prototyping Tasks Completed by Designers and Customers

Rapid Prototyping Project Tasks	*Project 1* *Designers*	*Project 1* *Customers*	*Project 2* *Designers*	*Project 2* *Customers*
Analysis				
1. Identify Audience	×	×	×	
2. Identify Instructional Need	×	×	×	
3. Identify Content to the Task Level	×		×	×
Design				
4. Identify Instructional Strategy	×		×	×
5. Write Design Memo and Obtain Approval	×	×		
6. Write General Content Outline	×		×	
Design and Development				
7. Identify Prototype Content	×		×	×
8. Build Prototype	×	×	×	
9. Review Prototype	×	×	×	×
10. Freeze Design	×	×	×	×
Development				
11. Complete Development	×	×	×	×
12. Conduct Pilot	×	×	×	×
13. Revise Product	×	×	×	×
14. Deliver Product	×	×	×	×

Figure 2 □ Observed Patterns of Concurrent Processing of Design Tasks



task. However, in Project 2 no design memo was written.

Customer tasks were identified from the designer's logs and the customer's interview. Customers were involved in fewer tasks than were designers, as would be expected. The customer was involved in analyzing the training needs; approving the design memo and content outline; providing input and feedback regarding content, activities, screen design, and system functionality; approving the prototype; and participating in the pilot. Although only one customer was part of this study, the number of customer representatives that were involved in the projects varied. In Project 1, the customer said, "As far as the user representatives, there were at times . . . from as high as six from down to as low as about three or four [persons involved]."

Concurrent processing. One hallmark of RP is that designers complete multiple tasks simultaneously, or engage in concurrent processing. The target RP model suggests general areas of concurrent processing, but it does not dictate the exact tasks involved. This study sought to identify the precise nature of RP concurrent processing. Log and interview data were analyzed to make these determinations. Results suggest that 10 of the 14 basic tasks were involved, in one project or another, in concurrent processing (see Figure 2).

The numbered items in Figure 2 refer to the 14 design and development tasks previously identified. These two configurations show projects unfolding with a combination of concurrent and linear task completion being performed by the designer, and the designer and the customer working together. They show a tendency to have two sources of concurrent processing, which first occurs in the early analysis stages of a project—typically combining audience and needs analysis activities. Later, it involves engaging in content identification intermittently throughout a project in conjunction with a variety of other tasks. Content identification (Task 3) occurred concurrently with strategy identification (Task 4), construction of the design memo (Task 5), prototype construction and review (Tasks 7, 8, 9 and 10), and final development (Task 11). Analysis tasks, then, share in all concurrent processing and tend to recur throughout a project. However, Figure 2 shows that there is considerable linearity in these projects. The linear aspect of the work was quite pronounced in the final stages of a project: conduct pilot, revise and deliver product. These tasks were always completed in a linear fashion. Figure 2 also highlights the overwhelming number of tasks that are performed collaboratively by the designer and the customer.

The Role of Rapid Prototyping in ID Process Enhancement

The second research question pertained to cycle-time reduction, product quality, customer satisfaction and enhancements to the ID process.

Design and development cycle-time reduction. The cycle-time question related to how designers

Table 5 ☐ Allocation of Designer Time by Phase and Task

Project Phase/Task	*Project 1 Working Days*	*Project 2 Working Days*
Analysis Phase		
1. Identify Audience	Not reported	1.0
2. Identify Instructional Need	10.0	Not reported
3. Identify Content to Task Level	4.0	14.0
Total analysis time	14.0	15.0
Percent of Total Time	17.7	20.2
Design Phase		
4. Identify Instructional Strategy	12.0	0.5
5. Write Design Memo and Obtain Approval	8.5	
6. Write General Content Outline	Not reported	5.0
Total Design Time	20.5	5.5
Percent of Total Time	25.9	7.4
Design/Development Phase		
7. Identify Prototype Content	Not reported	5.0
8. Build Prototype	5.25	10.0
9. Review Prototype	0.25	10.0
10. Freeze Design	Not reported	21.0
Total Design/Development Time	5.5	46.0
Percent of Total Time	6.9	62.2
Development Phase		
11. Complete Development	22.0	1.0
12. Conduct Pilot	10.25	5.0
13. Revise the Product	6.0	1.0
Total Development Time	38.25	7.0
Percent of Total Time	48	9.5
14. *Product Delivery*	1.0	1.0
Total Work Time	79.25	74.0

allocated their work time in an RP environment and how this time compared to non-RP projects. To answer the first part of this question, logs were analyzed to determine actual work time per general type of activity. Table 5 shows the work time reported from these two RP projects. As with of much research in natural settings, complete and precise data were not always available. Work time was not reported for four tasks in Project 1 and one task in Project 2.

Project 1, the design and development of a one-day instructor-led training program with matching online tutorial and documentation, took 79.25 days. Project 2, the construction of a one-day instructor-led training program with electronic presentation and documentation, took 74 workdays. The common perception of the designers and customer involved in these projects was that these cycle times were indeed reduced when compared with cycle time using a

Table 6 ☐ A Comparison of Design Cycle Time for RP and Non-RP Projects

Rapid Prototyping Projects Cycle Time Data		*Non-Rapid Prototyping Projects Cycle Time Data from Zemke (1997)*	
Type of Project	*Actual Work Days*	*Type of Project*	*Estimated Work Days*
Project 1			
1 day Instructor-Led Training, On-Line Tutorial (ca. 100 sequences) and Documentation	79.25	1 day Instructor-Led Training, On-line Tutorial with 100 sequences	50–100 37.5–50
		Total	87.5–150
Project 2			
1 day Instructor-Led Training, Electronic Presentation & Documentation	74	2 day Instructor-Led Training without Electronic Presentation	100–200

traditional model. Both the designer and customer from Project 1 shared this opinion. According to Designer 1, "We were able to produce a high quality product very quickly using rapid prototyping." The customer concurred by saying that "as far as if that [RP] makes it quicker or not, my guess would be yes."

Product quality enhancement. Product quality is typically based on learner achievement or on-the-job performance improvement. In this study, such data were not available. Consequently, product quality was defined as a function of its usability, a factor critical to the customer. Specifically, enhanced quality was viewed in terms of the length of its usability and the number of revisions required after delivery to the customer.

When asked if the product was an immediately usable, quality product, the customer associated with Project 1 indicated that the product was "definitely high quality . . . this process was a big part of that," and the product was immediately usable. The designer agreed. The product for Project 1 was used for two years, and then revised to accommodate software enhancements that the instructional materials supported. The product resulting from Project 2 is still in use one year after delivery. While usability and revision standards narrowly interpret product quality, they are realistic measures from an external consultant's point of view.

Customer and designer satisfaction. Customer satisfaction is a major issue for consultants, whether or not they are external to an organization. The customer in this study indicated that RP processes increased his satisfaction with the project. This satisfaction might be attributable to his seeing a working version of the product early in the project. For example, the Project 1 prototype was presented within 40 working days of the 79.25 days.

However, designer satisfaction is also critical because of the close working relationship between the customer and designer. Designer 1 in this study was fully satisfied with the RP methods; however, Designer 2 was unsure. He questioned the benefits of RP for producing instructor-led courses as opposed to computer-based training projects. Nonetheless, he emphasized the value of "an early review of some of the materials" and cited one example of an intended instructor's noting that "the instructor's guide lacked sufficient detail for her (a nonexpert) to conduct the training." Designer 1 indicated that RP ". . . puts something in front of the client up front—really early—and helps them see what their final project product is going to look like. So it can be real useful to a project."

DISCUSSION

Using Rapid Prototyping Methodologies

One aspect of this study was to examine the manner in which RP methods are used in actual practice environments, complete with the pressures and "messiness" of real work situations. We sought to discover two things: (a) Who does what? and (b) When do they do it?

Concurrent processing and nonlinear design. Even though there are little data to support the notion that most design is especially linear, traditional ID is often criticized for its linearity (Tripp & Bichelmeyer, 1990) . RP methodologies have been proposed as new nonlinear design paradigms (Tripp & Bichelmeyer, 1990). In many respects, the RP method studied here is not radically new. It employs the same fundamental techniques common to other instructional systems design models. In practice, this research shows that the design task sequences associated with this model vary from project to project. To a great extent these sequence variations are due to concurrent processing, a phenomenon that partially alters the presumed linear nature of ID.

No one concurrent-processing pattern was apparent in the projects studied here. The two patterns that were identified seemed to stem from project-specific factors, such as content, unique constraints, and product characteristics. We suspect that this would be the case with other RP projects as well.

The concurrent processing patterns we did find suggest other conclusions. First, the preponderance of concurrent processing pertains to needs assessment and analysis activities. While Gustafson and Branch (1997) have posited that there is less analysis in RP than in traditional ID, the opposite was true in the projects studied here. Thus, concurrent processing may be a way not only of decreasing design linearity, but also of expanding the analysis phase without increasing the overall cycle time.

The patterns also suggest that concurrent processing of design tasks and nonlinear design may *not* be always desirable. Figure 2 shows that a large portion of the design tasks were completed in a linear fashion; more than would have been expected in an RP environment. These linear phases of the project tend to involve development tasks, the very tasks that are typically completed *more* rapidly in RP projects than in traditional design efforts.

Collaboration. While there may be some debate as to the nonlinearity of RP processes, in the projects in this study collaboration occurred. (See Figure 2.) The specific RP process studied here directs the customer and the design team to "think through" the entire ID process in an effort to ascertain what the final product will be. Consequently, they not only must reflect on the objectives of the product they are creating, but must interact with and evaluate the prototype in terms of the needs of the end user. As the customer and design teams reflect upon each succeeding prototype, they gradually come to know whether or not the final product will meet expectations. Each version of the prototype reflects their thinking processes and conforms to their vision of the final product. This process is an example of Rathbun, Saito and Goodrum's (1997) notion of a prototype as an investigative tool used to develop the final product.

Customer-designer teams, working in an RP environment, can predict whether their recommended revisions can be implemented cost effectively and efficiently. For example, in Project 2 the customer and the designer evaluated an early prototype and decided that the final product would need a reference guide. They also identified necessary revisions in the instructor's and learners' guides. These changes, prompted only by a prototype early in the project, proved to be less costly and time consuming than would have been the case using traditional methods that would have necessitated reassembling the development team after product implementation for additional work.

Collaborative design seems to facilitate more customer satisfaction. This lesson corroborates the findings of Carr-Chellman, Cuyar, and Breman (1998) in their case study of user-design methods. However, we have found that true RP methodologies facilitate cost-effective design, as well.

The Role of RP in ID Process Enhancement

Ultimately, we are seeking ways to enhance ID, not only to document alternative models. The most important process-enhancement issues were those of cycle-time reduction and product improvement. These are the key interests of the field with respect to RP.

Cycle-time reduction. Instructional design and development time varies radically among projects depending on the nature of the product, designer experience, and project scope. Substantial variations can also be explained by the idiosyncrasies of project conditions. This study suggests that RP methodologies seem to reduce design cycle time. While it is difficult to fully ascribe these reductions to concurrent processing, it does seem possible to attribute them to the use of prototypes. Although the two projects studied here differed greatly, RP methods did seem to permit product improvements to be identified during the analysis and design phases, thus facilitating efficient development. This coincided not only with conventional wisdom and the impressions of the targeted designers and customer, but with the firm's previous experience that had been included in its marketing literature. Moreover, it is likely that the cycle time was shortened because of the assurance that products would meet customer expectations. These conclusions, however, are tentative because of the very small sample.

In an effort to more carefully explore the issue of cycle-time reduction, Zemke's cycle-time data (1997) were used as a non-RP baseline. These data clearly provide only a means of estimating the comparison. Actual work time has been calculated in the RP projects studied. However, Zemke's data were gathered from a variety of sources and present average work time based on actual experience. Zemke's sources raised cautions of the varying impact on cycle time of factors such as: (a) subject matter expert availability; (b) content considerations (e.g., Is the content technical or poorly defined? Is it stable?); (c) designer ability and knowledge of subject matter; and (d) the type of product being developed.

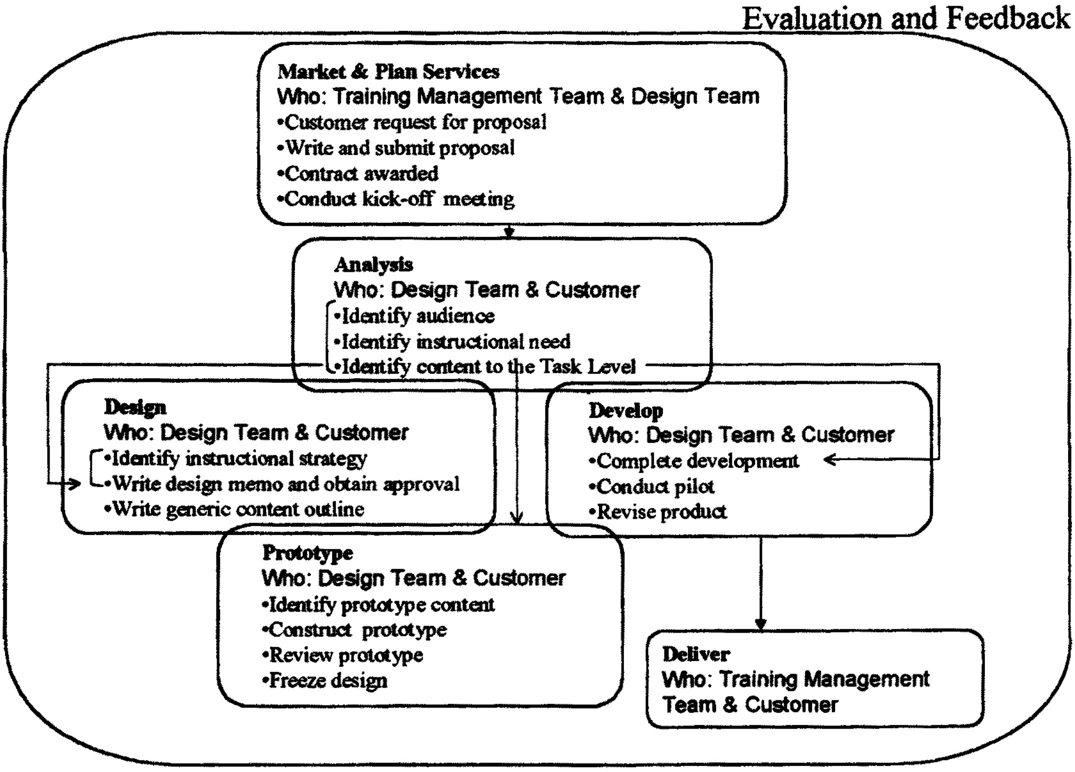
Zemke's data were presented in hours and have been converted to eight-hour workdays for comparative purposes here. Table 6 compares the target RP projects cycle-time data with those data reported by Zemke.

The project idiosyncrasies are worth exploring as well. Cycle-time data for Project 1 correspond to our conclusions, if one combines the time devoted to prototype construction and use with analysis and design time (see Table 5). In Project 2, on the other hand, an extremely large proportion of work time (62.2%) was dedicated to dealing with the prototype. This could be explained by two factors: (a) this was the first time the designer had worked with a prototype; but more importantly, (b) it was essential in this project that the entire designer-customer team reach a point-by-point consensus. Consequently, an unusually large amount of time was devoted to agreeing on the prototype and freezing the design. However, the customer in this project dictated the instructional strategy, which reduced the normal design time. It is also important to note that for both projects, *all* unreported time fell within the analysis, design and design-development phases. This further strengthens the position that increased analysis and design time reduces development time.

Product quality enhancement. It is commonly believed that the use of prototypes improves the quality of the final product (Moonen, 1996). While end-user performance typically functions as the measure of product quality in traditional design settings, usability is also an important element, and this is the factor more likely to be considered in relation to RP. For example, Corry, Frick and Hansen's (1997) case study illustrates the use of RP at a large midwestern university and its user-centered orientation to Web-site design. Usability was their ultimate measure of success. Likewise, Lange and Shanahan's (1996) use of RP to design, develop and implement an instructor-led school is another example of defining customer product satisfaction in terms of immediate and sustained usability.

In this study, usability and customer satisfaction were also the prime measures of product quality. Both criteria were met. The question is

Figure 3 ☐ A Revised Instructional Systems Design–Rapid Prototyping Model



whether this success is more likely to occur with RP or traditional design models. In an RP work environment, it seems that customer satisfaction should be virtually assured. If RP processes have been adhered to, usability should also be likely, but this higher standard cannot be guaranteed. RP, a form of traditional instructional systems design, shares the same advantages of all instructional systems design models. Part of the extra value seems to come from the added assurance of customer satisfaction and product usability that is derived from extensive customer involvement.

A Revised RP Model

Given the apparent validity of RP, it seems warranted to clarify the exact nature of these methods and to describe them in a model that may lend itself to more widespread use. Most RP models currently available are either extremely general or copyrighted by individual firms. There are no specific procedures for involving customers, completing specific designer tasks in each phase, or concurrent processing of design tasks. Moreover, there are no general time allotments provided for each phase. Consequently, it is difficult for the average designer to incorporate RP processes into work. Figure 3, based on the results of this study, shows a revised RP model that attempts to address most of these deficiencies. This proposed RP model has not been and needs to be used or tested for validation and to identify time allotments. It is designed to be comprehensive, encompassing the entire design cycle from marketing to delivery. It is designed to be appropriate for disparate ID projects, including paper-based and computer-based products. This model is designed to provide direction to designers and project management alike, but unlike the model targeted in this research, it may *not* be an appropriate marketing tool.

The model in Figure 3 is not linear, in spite of the typical flow from analysis to design to development. The critical phases—analysis, design, prototype, and develop—overlap one with another. The model is detailed. Concurrent processing is illustrated within and between phases both by bracketing tasks and by connector arrows. For example, all tasks within the analysis phase are performed concurrently. On the other hand, the task of identifying content to the task level is done concurrently between four phases—analysis, design, prototype and develop. Evaluation and feedback, a process that is applied through continual customer involvement throughout the entire project, encircles the model.

Unlike most ID models, this proposed RP model specifies the roles associated with each major phase. Roles are identified to facilitate project management and reduce role conflict. The core phases pertain to joint designer-customer activities. The business phases, "Market and Plan Services" and "Deliver," pertain to training managers rather than designers.

CONCLUSIONS

This study investigated the use of RP methodologies in natural settings. It sought to document actual RP practice in diverse situations so that others could replicate such methods, and to determine the extent to which RP enhances the traditional approach to ID and development. The projects studied show ID efforts that created products that were usable for a conveniently long period of time without revision, delivered in a shorter period of time than would have been expected using traditional techniques, and received by satisfied customers who had been involved throughout their development. In other words, the RP methods lived up to their promised benefits.

RP appears to provide one solution to the pressures currently faced by most designers to produce high quality products in less time. It is a process that continues to warrant study. We are only beginning to understand the implications RP has for key design and development issues, such as the nature of problem definition, the impact of organizational contextual variables on work time, the nature of designer decision-making when using these methods, and the designer expertise and resources that are requisite to successful use of these models. These are topics that do not lend themselves to simulations or controlled studies. They demand research in actual work settings, which means that researchers and design practitioners must cooperate to fully explore the potential of this methodology. □

Toni Stokes Jones is Assistant Professor in the Teacher Education Department at Eastern Michigan University. Her e-mail address is tsjones@online.emich.edu.

Rita C. Richey is professor and program coordinator of Instructional Technology at Wayne State University, Detroit, MI. Her e-mail address is rrichey@coe.wayne.edu.

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