1. Introduction

One of the goals of research in instructional technology is to develop and study new ways of utilizing technology to support effective instruction. Recently, using the Internet to give learners efficient access to "anywhere anytime" learning has come to the forefront of this research agenda. Although there are several positions taken by instructional technology researchers, most share a common focus: small, digital, reusable, educational resources. This approach is known as:

- Educational software components (Roschelle, 2001)
- Sharable content objects (ADL, 2001)
- Knowledge objects (Merrill, 2001)
- Educational objects (Sphorer, 2001)
- Learning objects (IEEE/LTSC, 2001)

In my work I have called these resources "learning objects," following the IEEE's Learning Technology Standards Committee's terminology, defined them as "any digital resource which can be reused to facilitate learning" (Wiley, 2000), and have argued that this definition is a significant improvement over the IEEE/LTSC's definition, which "fails to exclude any person, place, thing, or idea that has existed at anytime in the history of the universe" (Wiley, in press-a).

These nonrival educational resources show great promise for helping instructional technologists reach their goal of efficient, effective, appealing instruction (Reigeluth, 1999) anywhere, anytime. However, the field is in desperate need of new theoretical frameworks for using these resources. In this proposal I will argue that current approaches to using learning objects are decontextualized, isolationist, and dehumanizing, and have failed to yield the educational fruit learning objects are capable of bearing, namely, enabling high quality, anywhere anytime learning environments.

Therefore, I propose to conduct a basic research program directed at *devising theoretical frameworks and methodological strategies for designing and employing learning objects in online learning environments*. To develop these new frameworks and strategies, I will undertake an empirical program based on ethnographic analyses of existing online learning communities, employing the "person-acting-with-mediational-means" as the unit of analysis (Wertsch, 1991). Rather than viewing learning objects as decontextualized artifacts existing independent of learners' interactions with them, Wertsch's analytic method will allow the research to focus on the ways in which the resources mediate the achievement of online learners goals within their broader historical, cultural, and institutional context. Instead of engaging in new development or community building efforts as part of the research, I will carry out the research in the context of existing online learning and work communities, including those forming around our Instructional Architect system (Recker & Wiley, in press; funded under NSF grant #DUE-0085855).

Specifically, there will be three broad types of research outputs from the proposed work:

(1) **Development of learning objects design and utilization frameworks and techniques.** The first product of this research will be a group of theoretical frameworks and strategies for designing and planning for the use of learning objects. To a large extent, the exact nature of the new frameworks and techniques must develop as the project progresses. However, I will employ Hine's (2000) virtual ethnography method in conjunction with Wertsch's (1991, 1998) mediated action analytic framework. This research will build on my previous work in building taxonomies of learning objects types (Wiley, in press-a) and describing problem-centered possibilities for their use (Wiley, in press-b).

(2) **Application of the frameworks.** Second, in parallel to their development, I will apply the frameworks to separate online learning and work communities in order to formatively evaluate their explanatory and predictive power in answering questions, including: in what ways do learning objects facilitate the accomplishment of goals in online learning and work communities? In what ways do they interfere with the accomplishment of these goals? What roles does the broader community context play in

mediating the effective utilization of learning objects? Are there any replicable design patterns evident in learning objects selected for use more frequently than others?

(3) Development of new resources for teaching information technology literacy. Many of the existing online learning and work communities focus on learning and performance in information technology domains, such as computer programming. As part of the application of the frameworks, new learning objects will be created according to the frameworks and strategies described above and contributed to appropriate communities. These resources will also be placed in the NSF's National Science Digital Library.

I believe that this research project will help lay the foundation for my future work in research and education. I am devoted to developing rigorous theoretical accounts and strategies that can guide the educationally successful design and deployment of learning objects. In past work, I have focused on describing the types of learning objects that could exist (Wiley, 2000) and strategies for using learning objects in individual instruction (Wiley, in press-a). This project will allow me to begin work in a new and, I believe, productive direction: I will build a framework, suited to a range of scientific domains, that attempts to describe the manner in which online educational resources mediate the learning efforts of members of an online community of learners.

2. Why do we need new frameworks?
To this point I have simply asserted that while instructional technologists are employing learning objects (by a variety of names), radically new frameworks for their design and use are required. In this section I will argue for this assertion. I will begin by elaborating current learning objects approaches to facilitating anywhere, anytime learning, and contrast the assumptions of these approaches with current research in learning. I will then begin to characterize the type of framework I believe is necessary to support anywhere, anytime learning.

2.1 Current approaches using learning objects
While there are a diversity of names for learning objects, the ways in which they are utilized are strikingly similar. This section briefly reviews one of the most elaborated and representative of current approaches to learning object utilization, and provides a summary of other approaches.

Due in part to its own internal training demands, Cisco Systems, Inc. has become a major player in the online learning space. Building on existing instructional design research, Chuck Barritt and Deborah Lewis developed Cisco's Reusable Learning Objects Strategy in a 2000 white paper (Barrit & Lewis, 2000). Their framework is outlined as follows:
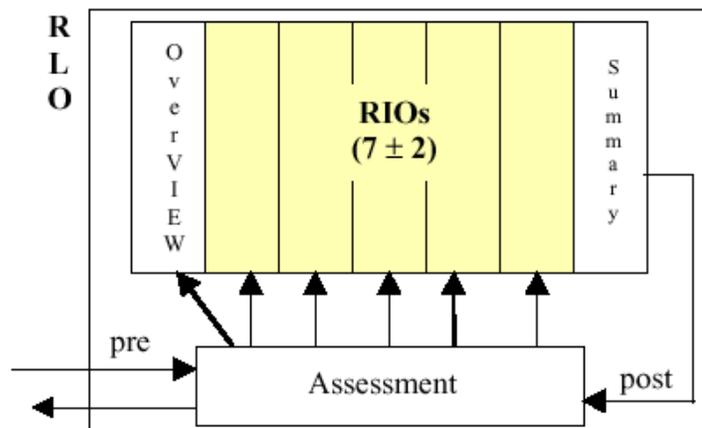
The RLO Strategy is built upon the Reusable Information Object (RIO). An RIO is granular, reusable chunk of information that is media independent. An RIO can be developed once, and delivered in multiple delivery mediums. Each RIO can stand alone as a collection of content items, practice items and assessment items that are combined based on a single learning objective.

> Individual RIOs are then combined to form a larger structure called a Reusable Learning Object (RLO)…
>
> A Reusable Learning Object is created by combining an Overview, Summary, Assessment and five to nine (7+/-2) RIOs.
>
> An RLO is based on a single objective, derived from a specific job task. Each RIO is built upon an objective that supports the RLOs objective (p. 2-4).

The RIO/RLO design process begins by analyzing a task down into its constituent parts, and learning objectives are designed from these constituent tasks. RIOs are then designed in order to teach the specific objectives, and practice and assessments are designed in order to measure student mastery of the objective. As evidenced in the graphic from the white paper, the RIO is presented in sequence with 4 - 8 others in order to comprise an RLO, or complete learning experience. This methodology could provide significant benefits to Cisco's instructional developers by allowing them to reuse existing educational resources much they way software engineers reuse objects in the object oriented programming paradigm. The Cisco paper acknowledges work by Mager (1975), Merrill (1983), and Clark (1989) as its theoretical foundations (Barritt & Lewis, 2000).

2.1.2 Summary of learning objects approaches
The methods explicated by Cisco and other employers of learning objects are surprisingly similar, drawing largely on the same theoretical work from the 1980s or earlier, including work done by Mager (1975), Bloom (1956), Merrill (1983), Clark (1989), and others working in behaviorist or cognitivist instructional paradigms.

The United States Department of Defense's Advanced Distributed Learning Network Initiative is similarly positioned. The following quote from its Sharable Courseware Object Reference Model (SCORM; ADL, 2001) specification summarizes the assumptions behind current learning objects approaches:

> Empirical studies have raised national interest in employing education and training technologies that are based on the increasing power, accessibility and affordability of computer and networking technologies. These studies suggest that realizing the promise of improved learning efficiency through the use of instructional technologies—such as computer-based instruction, interactive multimedia instruction and intelligent tutoring systems—depends on the ability of those technologies to tailor instruction to the needs of individuals. In contrast to classroom learning, these approaches enable the pace, sequence, content and method of instruction to better fit each student's learning style, objectives and goals…
>
> The dilemma presented by individually tailored instruction is that it combines an instructional imperative with an economic impossibility. With few exceptions, one instructor for every student, despite its advantages, is not affordable. Instructional technology promises to provide most of the advantages of individualized instruction at affordable cost while maintaining consistent, measurable, high-quality content (p. 17-18).

There are three significant, implicit assumptions in this statement:

1. A one-on-one instructional model is preferable above others,
2. human interaction in large scale learning environments is economically impossible, and
3. automation via intelligent instructional systems is the only viable solution to providing anywhere anytime learning.

The importance of these assumptions cannot be overstated as they color all the design decisions made by participants in the SCORM and other learning objects efforts (e.g., Cisco, NETg, Click2Learn).

2.2 Disparities between learning objects approaches and current research on learning
Disappointingly, while they harmonize well with 1980s learning research, the assumptions of current learning objects approaches contradict recent research on learning. Three of the main weaknesses of current large-scale online learning approaches with regard to teaching and learning are outlined below.

2.2.1 Decontextualized learning
The instructional design behind learning objects is increasingly moving toward decontextualization. This is true because of an inversely proportional relationship between the size of a learning object and its potential for reuse. As I have demonstrated in previous research with Drs. Mimi Recker and Andrew Gibbons (Wiley, Recker, & Gibbons, 2000), learning object "use" is better described as "contextualization." That is, when an instructional designer or automated system "uses" a learning object, they are actually placing the object into an instructional context. The relationship between internal context of the learning object itself and the external context into which it is being placed determines whether or not the object "fits" into that context. The less specific the internal context of the learning object, the more instructional contexts into which it will "fit." Conversely, the more specific the internal context of the object, the fewer instructional contexts into which it will "fit." Figure 1 demonstrates this relationship, using an analogy of learning objects as puzzle pieces.
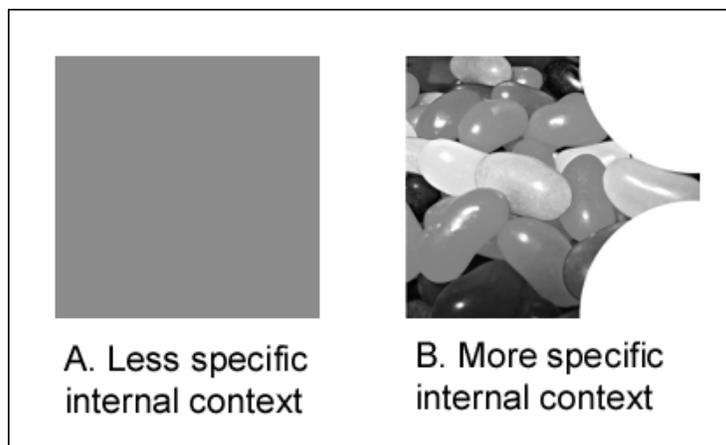
Figure 1. Two puzzles pieces, demonstrating how internal context influences the number of external contexts into which learning objects will successfully fit. Piece A could fit together with a variety of other pieces of varying colors and shapes. Piece B would fit with far fewer pieces, specifically, it would only fit within a context matching its own in terms of shape and pattern.

In the language of digital educational resources, an image of a molecule is usable in far more instructional contexts than an entire lesson on molecular bonding.

Instructional designers of learning objects problematically focus on removing as much context as possible in order to maximize the reuse of the learning objects they create. A paradox arises because modern learning theorists are increasingly emphasizing the preeminence of context in learning, using language such as "social context" (Vygotsky, 1981); "cultural, historical, and institutional setting" (e.g., Wertsch, 1991), and "situatedness" (e.g., Lave & Wenger, 1990; Jonassen, 1991). While far transfer (implying a type of context independence) is the goal of most instruction, the social, historical, cultural, and institutional contexts of learning are crucial factors that must be considered in the design of instruction if it is to succeed. The simple alignment or sequencing of decontextualized educational resources does not produce a meaningful context for learning. *While economically sensible, the drive toward decontextualization may actually be counterproductive from the standpoint of student learning*.

2.2.2. Megaphone not mediator
Learning objects are generally deployed as "content chunks" or "information containers." That is, they are utilized as glitzy information dumps, or "lectures with high production values," as if all that online or

distributed learning required were a larger megaphone for the instructor. As learning theorists push for more contextualized, real-world, authentic instruction, instructional strategies such as case-based scenarios (Schank, Berman, & Macpherson, 1999) or problem-based learning (Albanese and Mitchell 1993; Vernon and Blake, 1993) have emerged in response. When learning is understood in the context of problem solving, learning objects and other resources change from info-capsules that transfer inert knowledge from expert to novice, into semiotic tools that mediate and shape the learners actions (Wertsch, 1985), like the cards in Vygotsky's (1978) interpretation of Leont'ev's (1932) forbidden colors task.

In the forbidden colors experiment, subjects were asked to describe a number of items without using the name of any color more than once. Subjects were provided with cards corresponding to colors to use during the experiment. Many younger subjects were unable to use the cards successfully, but older subjects used the cards as tools to mediate their performance of the task; for example, turning a card face down once its color had been used. This "tool" aspect of learning objects, in other words, the manner in which learning objects mediate problems solving activities, remains almost completely unexplored. Wertsch's (1991) call for social science research to focus on mediated action would suggest that neither learners working in online environments or the resources they use in those online environments can be studied fruitfully in isolation. Rather than studying learning objects out of context, the research unit of analysis must focus on learners' actual uses of the objects within a learning context. Wertsch (1991) reminds us that, "*Only by being part of action do mediational means come into being and play their role. They have no magical power in and of themselves* (p. 119)."

2.2.3 Scaling through automation

Many individuals and institutions pursue learning objects research with the goal of reaching "anywhere anytime" learning through computer-automated assembly of learning objects personalized for individual learners (e.g., Martinez, in press; Hodgins, 2000; IEEE/LTSC, 2001; ADL, 2001). And the cost savings of automating instructional design are obvious. But while the model of one learner interacting with one computer matches very well with the 1970s view of computer-based instruction (refs), an isolationist approach is at odds with what modern learning theorists are increasingly emphasizing – the importance of collaboration (e.g., Nelson, 1999), cooperative learning (Johnson & Johnson, 1997; Slavin, 1990), communities of learners (Brown, 1994), social negotiation (Driscoll, 1994), and apprenticeship (Rogoff, 1990) in learning. *Even with significant pedagogical considerations set aside, it seems paradoxical that we would we put hundreds, thousands, or millions of learners in front of advanced communications technology so that they can retrieve data from a supposedly intelligent machine instead of interacting with other people.*

2.3 Other practical problems with current learning objects approaches

In addition to the disconnect between current learning objects approaches and current research in teaching and learning, there are several practical obstacles to successfully implementing current learning objects models. This section describes two such problems.

2.3.1 Specially designed for reusability

While the primary design criterion of learning objects-based approaches is generally reusability, considerations of granularity (i.e., how "big" the learning object should be) and architecture (i.e., the structure according to which the objects should be assembled) frequently require designers to reformat all existing content before it can be "reused" in a given learning objects system. For example, an existing PDF user manual for a piece of software or hardware may be broken up into several smaller chunks, converted into XML, and stored in a database. Wiley (2000) criticized Merrill's (1999) Instructional Transaction Theory of being particularly guilty of this problem, requiring literally every object to be specially prepared and formatted. In other words, forty-some odd terabytes of existing media on the publicly accessible Internet would be unusable without extensive retooling, and this is true of other learning objects approaches as well (Cisco, NETg, Click2Learn, SCORM). *The vast majority of existing digital educational resources could not be reused in current learning objects systems designed to support reusability, such as those based on SCORM.*

2.3.2 The reusability paradox

Because the primary design goal of learning objects is reusability in a variety of diverse learning contexts, learning objects are generally designed in a highly decontextualized manner (e.g., South & Monson, in press). Reigeluth and Nelson (1997) have argued that when working with instructional media of any kind, educators first deconstruct the materials into component parts in order to reassemble the media according to their individual needs. By designing "pre-deconstructed" instructional media, it is believed, greater development efficiency can be achieved as educators bypass the step of personally deconstructing media. However, Wiley, Recker, and Gibbons (2001) have argued that extremely decontextualized media are actually more costly and difficult to utilize in instructional development because of (a) difficulties in indexing extremely decontextualized media for human discovery and use, and (b) computers' inability to make meaning, and therefore combine primitive media into instructionally meaningful units.

In the semiotic sense, learning objects and other educational resources are signs whether they be text, graphics, audio, animation, or otherwise. The learning objects user's task of combining individual resources into instructionally meaningful lessons is similar to the speaker's task of combining individual words and utterances into meaningful communication. Inasmuch as this is true, Vygotsky's (1962) notion of the "influx of sense" applies to learning object assembly. In language, the meanings of words and sentences that proceed and follow an individual word, such as the word "sense" in the proceeding sentence, color the meaning of that word. In other words, proceeding and following utterances significantly alter the meaning of a word or other utterance. Vygotsky (1962) wrote:

> The senses of different words flow into one another - literally "influence" one another - so that the earlier ones are contained in, and modify, the later ones. Thus, a word that keeps recurring in a book or a poem sometimes absorbs all the variety of sense contained in it and becomes, in a way, equivalent to the work itself.

Creating a meaningful utterance becomes an act in which words and other utterances with overlapping and context-absorbing meanings are intermingled to create meaning. Returning to learning objects, the combination or sequencing of educational resources creates a context in which the resources color and absorb each other's meanings. In all but the most basic instructional applications, such as "drill-and-kill" memorization training, computers have no hope of engaging in the type of complicated meaning making required to create meaning-full instruction from learning objects. This implies that humans will have to assemble learning objects by hand for all but the most rudimentary instructional content. *Surprisingly, while the most decontextualized learning objects are reusable in the greatest number of learning contexts, they are also the most expensive and difficult for instructional designers to reuse.*

2.4 Toward a new theoretical framework

In summary, though there is much to build on, there is still a great deal of work to be done in designing theoretical frameworks for the design and utilization of learning objects. For the present project, existing approaches must be reexamined in light of current research in teaching and learning, take into account the difficulties with current approaches described above, and grounded in accounts of actual use. The unit of analysis can be neither the online learner nor the learning object itself, but must be the "person-acting-with-mediational-means" (Wertsch, 1991), or more specifically, the online-learner-problem-solving-using-learning-objects-as-tools.

To build the new framework, I will begin from my previous research. In prior work, on my own and with both the Digital Learning Environments Research Group at Brigham Young University and the Reusability, Collaboration, and Learning Troupe at Utah State University, I have attempted to describe both ontological and functional aspects of learning objects. With partial funding from the Edumetrics Institute I have created a taxonomy of learning object types available to instructional designers, along with strategies for instructional designers using learning objects in complex domains (Wiley, 2000). I have critically examined the prevailing metaphor of learning objects, the LEGO block, suggesting a more robust metaphor built around molecular bonding which captures the notions of fit in learning object contextualization (Wiley, in press-a). With funding

from Utah State University I have demonstrated a system for the peer-to-peer sharing of learning objects and built democratic models of object use directly by learners (Wiley, in press-b). With funding from the Cisco Learning Institute, I am analyzing individuals' understandings of learning objects and designing a beginning course for persons unfamiliar with the learning object concept. Finally, in my edited volume "The Instructional Use of Learning Objects" and in later work, I have pioneered the application of constructivist learning theory to learning objects-based approaches to instructional design (Wiley, in press-a; Wiley, in press-b). This broad base of learning objects research positions me well to carry out the proposed activities.

I believe that a more rigorous understanding of the ways in which online learners actually use learning objects, that is, a more rigorous understanding of the ways that learning objects mediate online learners' problem solving activities, will provide significant value to science, mathematics, and technology education, and serve to launch a very productive course of personal research. In the next section, an example of online learners using learning objects to solve problems is presented.

3. An example of online learners problem solving using learning objects as tools

To this point I have asserted that communities of learners who use learning objects to problem solve exist online. In this section I present a brief example of an interaction from such a community, comment on the example in terms of the obstacles described above, and compare the case to current learning objects approaches.

3.1 Example case

The following excerpt is taken from the PerlMonks website section titled "Seekers of Perl Wisdom." PerlMonks is an online community where a variety of people learning the PERL programming language and working through the problems common to those learning the obtuse language interact and collaborate to solve problems (http://www.perlmonks.org/index.pl?node_id=98134&lastnode_id=479). Portions of the interaction have been removed in order to preserve space.

In this example we see a condensed form of the collaborative problem solving process described by Nelson (1999).

- Problem solving group membership is implied by membership in the community,
- learners negotiate a common understanding of the problem through a series of questions and restatements,
- learners' roles in the problem solving are implied as one learner poses the problem and responds with further clarifications, thoughts, or ideas,
- learners gather information from a variety of sources, including PERL modules, code samples, Postgres output, and Postgres documentation,
- a solution is agreed upon and implemented, and
- further questions are raised, beginning the problem-solving cycle anew.

Unique ID
by nlafferty on Jul 19, 2001 at 16:39

nlafferty has asked for the wisdom of the Perl Monks concerning the following question:

I want to know how to generate a unique id for every row i enter into my postgreSQL DB. So that a unique id is specified to a variable, which i can INSERT into the row along with my other information.

Re: Unique ID
by lhoward on Jul 19, 2001 at 16:46
The two easy ways to do this with Postgres. One is to specify the ID col. as serial type, which will cause it to be auto-incrementing (i.e. when you insert a row, it will automagically get a new, unique val in the serial col).

Additionally, you can use a postgres sequence to keep track of the ID, and query it with postgres's nextval function whenever you need a new value:

```
my $sth=$dbh->prepare("select nextval(?)");
$sth->execute("seq_name");
my $id=$sth->fetchrow();
$sth->finish();
```

Of coruse, you can also do this the old-school way too (but its less efficient to do it this way):

Have a table to store the last assigned ID. When you need an ID, lock that table, read the value out of it, write the value+1 back to the table, and then unlock it.

Re: Re: Unique ID
by nlafferty on Jul 19, 2001 at 17:05
So if i use a serial type then i do not have to use the sequence as well. Or do i have to use a combination of both?

Re: Re: Re: Unique ID
by lhoward on Jul 19, 2001 at 17:28
The serial type creates and uses a sequence behing the scenes, but its operation is transparent to you. You do not need to create an additional sequence to use it. See... (using psql, Postgres's command line tool):

test=# create table foo(ID serial NOT NULL,bar text, constraint foo_pk primary
<program output removed to preserve space>

I find postgres sequences to be most useful when you want to share one unique ID across tables and when you don't have a master table to store it in (or don't have a table that will always be inserted first). Or when you want to assign something outside of the DB (at least at the time of assignment) a unique ID.

Re: Unique ID
by lachoy on Jul 19, 2001 at 17:00

ObPerl: You can also use a wrapper like (plug plug) SPOPS(link) module to do this for you -- there is example code at this node(link).

Chris
M-x auto-bs-mode

Re: Unique ID
by lestrrat on Jul 19, 2001 at 17:07

If this unique ID does not have to be any thing in particular, you might as well use the oid column. oid is unique for every single row in the database, and is created

when you insert a row.

It's sort of a "hidden" field, so when you query, you have to do

    SELECT oid,* FROM table;

    # if you already know your oid..
    SELECT * FROM table WHERE oid = x;

This is so much easier than maintaining a sequence.... and is universal for Postgres.

  Re: Re: Unique ID
  by nlafferty on Jul 19, 2001 at 17:14
  This is originally how i thought would be a good way to handle this. I'll give it a
   shot...thank you ;)

  Re: Re: Unique ID
  by nlafferty on Jul 19, 2001 at 19:36
      So how would i do a delete statement WHERE oid = "$oid" ?

_____

3.2 Discussion of the example case
In this section, the example case is discussed in terms of the research context established above.

        3.2.1 Learning objects
Thinking about the case in terms of learning objects, it immediately becomes apparent that educational resources are generally defined in an unnecessarily narrow manner. Some digital content such as Internet-accessible PERL modules, sample code, and the Postrges database's user manual are referenced and discussed. Also, the discussion itself as captured on the web board may be seen as a learning object in the traditional sense. This utilization agrees well with the notion of "learning objects as content nuggets." However, the Postgres database program itself is also used as an educational resource in the dialog above; specifically, relevant output from the software is recorded and shared for use in the problem solving process. Additionally, when stepping back the researcher is prone to notice that the website software itself is mediating the problem solving process by taking questions and responses, displaying these in an easy to navigate, threaded manner, etc. These environmental affordances are important to consider in defining the mediational boundaries. The first take-away from this examination is that our conception of learning object (or mediator) must be broadened from the traditional concept of "small information chunk."

        3.2.2 Problems relating to current research in teaching and learning
            3.2.2.1 Decontextualized learning
The various resources employed in the problem solving process in the example are not highly decontextualized chunks of content presented in a simple sequence. The resources are highly contextualized in their own right (e.g., an entire database user guide), but more importantly they are held together by the context provided by the problem solving activity. For example, links to PERL modules appear with a context-dependent explanation of why the resource is relevant to the current problem. As opposed to a LEGO metaphor in which the resources connect directly into a meaningful structure, these objects are used like bricks held together and made meaningful by a contextual mortar; specifically, the prefacing and proceeding material around each resource provides scaffolding context that supports the learners' meaning making.

            3.2.2.2 Megaphone not mediator
While some of the resources in the case are simply information dumps, many of them are functional directives that nlafferty can employ in his own problem solving activity. Additionally, the resources

are not just presented as static information. They serve as foci of discussion, stimulating new ideas, and mediating the thinking of the group.

3.2.2.3 Scaling through automation

The most significant departure of the example above from conventional learning objects approaches is that it relies on human beings to locate, assemble, and contextualize the resources. Although the tragedy of the commons (Hardin, 1968) would suggest that such voluntary collaborations are not sustainable over time, the emergence of the Internet, and specifically the Free or Open Source Software movements, have shown peer-to-peer communications technology's ability to put people in symbiotic, "you answer my question, I'll answer yours" relationships. The gift culture described by ethnographers of the Free/Open Source movements such as Raymond (1999) and Himanen (2001) is one explanation of this phenomenon. I have argued elsewhere that a distributed expertise model obtains in sufficiently large distributed learning communities, meaning that because expertise exists across the community no individual community member is burdened with primary responsibility for answering questions or providing feedback. As problems arise related to the expertise of an individual, that individual may or may not choose to provide help. If the community is of sufficient size (as PerlMonks and many other online communities are), the distribution of expertise and effort provides timely problem solving support without unduly burdening any individual (Wiley, in press-b).

3.2.3 Problems relating to the practical use of learning objects

3.2.3.1 Specially designed for reusability

The learning objects employed by learners in this example have not been taken apart and made to conform to a standard grain size. Neither have they been forced to conform to an architectural standard which requires special JavaScript hooks to allow the objects to communicate with a learning management system. Existing resources have been reused just as they existed previously, without any special preparation.

3.2.3.2 The reusability paradox

Finally, while there is no direct evidence that the learners who volunteered learning objects and explanations of their relevance to the given problem had an easy time locating and using the learning objects, given the voluntary nature of the community and lacking any indication of extrinsic motivation, we may assume they did so.

3.3 Comparison of the sample case and current learning objects approaches

I have argued above that current learning objects approaches suffer from a number of practical and pedagogical difficulties. However, when reviewing the example case in light of these various criticisms, none seemed to apply. It would appear that learning object use "in the wild," that is, educational resource use unmarred by instructional design and development methodologies, exhibits none of the weaknesses of contrived approaches.

The sample case includes a large number of learners, yet scalability (in terms of teacher-bandwidth) is not an issue. Learners are provided with meaningful learning support "anytime anywhere" yet the case is rich with human-to-human interaction. Learning objects are successfully embedded in a meaningful learning context, but the discovery and use of the objects is done by humans without over burdening any individual (i.e., without exhibiting scalability problems). It is because these naturally occurring methods seem superior to existing approaches that I believe the research plan outlined in this proposal to be so significant, both to the field at large and to myself as a launching point for my career.

4. The plan of work

The goal of the proposed work is to *devise new theoretical frameworks and strategies for designing and using learning objects*. As I hope to have suggested in previous sections, the work has the potential to contribute significantly to basic research in instructional technology, and specifically science, mathematics, and information technology teaching and learning. If we can improve our understanding of the ways in which

learning objects can be effectively designed and used, significant improvements in the quality and availability of online education may be effected.

In line with the goals of the CAREER program, I have in mind a long-term effort. Therefore, to a certain extent, the plan of work must develop over the period of the grant. However, the broad shape of the research is clear, I know the context for the research, and I can build off of promising prior work. In this section of the proposal I will lay out the proposed research activities.

4.1 Research Context

As stated above, I will carry out the work in the context of existing online learning communities rather than first working to create new communities. This is advantageous both because the research will "hit the ground running" and because any learning community I designed would be colored in a way making it inappropriate for grounded research. The following online learning communities have been identified as candidates for the project.

- The Linux Kernel project, an international project in which programmers are collaborating to research and implement the core kernel of a completely free Unix-like operating system (http://www.tux.org/lkml/ and http://www.kernel.org)
- The Gnome Project, an international project in which programmers are collaborating to research and implement a completely free windowed desktop environment for Unix-like operating systems (http://www.gnome.org)
- Slashdot, a large web-based community (30,000 registered) in which people with interests in information technology developments can track recent events, ask questions on a variety of technology-related topics, and receive answers (http://slashdot.org/)
- Perl Monks, a web-based community in which programmers collaborate to help each other learn to use and solve problems involving the PERL programming language (http://perlmonks.org)
- Microsoft.newsgroups, in which users of Microsoft software collaborate to help each other learn to use and troubleshoot various Microsoft products, including operating systems, productivity applications, and integrated development environments for a number of programming languages

These communities may not seem like traditional online *learning* communities because they are not. They are communities of problem solvers learning in real world contexts mediated by a variety of online resources and communications tools. As such they are appropriate targets for the current research. Additionally, they are all communities of information technology learning. While the main goal of the research is developing new theoretical frameworks for learning object design and use, the selection of information technology communities will likely yield important insights into information technology learning.

The Department of Instructional Technology at Utah State University, one of the top five instructional technology programs in the country, provides an ideal setting for the proposed project. In addition to myself, three of the most respected and active academics in the nation in the area of learning objects are on faculty, Drs. David Merrill, Andrew Gibbons, and Mimi Recker. We four and a number of graduate students comprise the Reusability, Collaboration, and Learning Troupe, a research group focusing on learning objects research with existing partnerships with the University of California (under NSF DUE-0085855), the Cisco Learning Institute (under contract), Microsoft Research, the Utah Educators Network (a statewide K-12 organization), and others. The department and research group provide access to top quality graduate students, research partners, and public schools.

4.2 The core empirical work

The core empirical efforts will be based on techniques similar to those used in the examination of the sample case above, though much more thorough. Initial data gathering will be accomplished through an ethnographic approach modified for use in online settings (Hine, 2000). While acknowledging the host of methodological problems involved with online ethnographic research, Hine describes her approach as "adequate for the practical purpose of exploring the relations of mediated action" (p. 65).

The five years will be broken into three phases. During Phase I, which will last for the first two years of the project, the empirical and analytical techniques will be employed and refined appropriately. In Phase II, which will run for the third and fourth years, the revised empirical and analytical techniques will employed again during a second iteration of study and analysis. Finally, during Phase III (year 5), analyses will be finalized and published. (See Table 1 for the project timeline).

	Research Activities	Education Activities
Phase I Years 1-2	• Selection of two online learning communities • Ethnographic study of selected communities • Analysis of data following Wertsch (1991) • First draft of new framework • Article writing	• Integrate data gathering, analysis, and framework building into courses as appropriate • Implement new framework within courses • Integrate evaluation of new framework into courses as appropriate • Develop digital library of exemplary resource use cases
Phase II Years 3-4	• Selection of two online learning communities • Ethnographic study of selected communities • Analysis of additional data following Wertsch (1991) • Second draft of new framework • Article writing	• Iterate Phase I activities
Phase III Year 5	• Finalize new framework • Article writing	• Iterate Phase I activities

Table 1. Timeline for the proposed project.

4.2.1 Phase I (Years 1&2): First iteration and improvement of techniques

During Phase I, I will select two online learning communities for ethnographic study. Because the communities to be studied are at least two years old with public, full archives, I will begin by analyzing the existing record of interactions (analysis techniques are explained below). I will then join the community as both researcher and participant, fully disclosing my intentions (Herring, 1996). This real-time engagement will allow targeted questions regarding others' participation, broader interviews, and a general responsiveness not available through document review. Boundaries of the communities will not be assumed *a priori*, but examined over the course of the study. Again, following Hine (2000), I will also draw on my own online, mediated problem solving experience during the research as a data point. I will reflect on the appropriateness and utility of the techniques employed during Phase I and plan Phase II research activities accordingly.

4.2.2 Phase II (Years 3&4): Second iteration

Phase II will involve the same empirical work as Phase I, using two additional online learning communities and an improved data gathering methodology.

4.2.3 Phase III (Year 5): Final analysis and publication

In Phase III I will draw on data from the first two cycles to finalize the framework. Significant time will be devoted to writing papers and planning future research.

4.3 Analytic techniques

As mentioned above, Wertsch's (1991, 1998) mediated action framework will be employed in the analysis of the ethnographic data. This involves focusing on the person-acting-with-mediational-means, as opposed to either the learner or the learning objects. The lenses through which the analysis proceeds are those of voice, dialogicality, social languages, speech genres, and privileging. Voice includes considerations of the speaking personality and the addressee of the speaker's utterance. Dialogicality involves the manner in which "one speaker's concrete utterances come into contact with, or 'interanimate,' the utterances of another" (Wertsch, 1991, p.54). Social languages deal with styles of "discourse particular to a specific stratum of society (professional, age group, etc.) within a given social system at a given time" (Holquist & Emerson, 1981, p. 430), for example, the jargon of physicists. In contrast to social languages, speech genres are characterized not by social strata of those who employ them, but the typical social situations in which they are employed, for example, the language of the formal science classroom. Finally, privileging concerns choices persons make among mediational means when alternatives are available, for example, why communicate via a web board when one learner could e-mail another directly?

The results of these analyses will be used as inputs into a method for creating coherent instructional design models (Wiley, 2000). I have previously extended Nelson's (1998) instructional design theory development method, and used the resulting methodology fruitfully with approaches to using learning objects in complex domains (Wiley, 2000).

The analysis will generally proceed as follows: mediated interactions within the qualitative data are examined for patterns or categories through the lenses described above. Categories are constructed, linked, and densified (Corbin & Strauss, 1998), much as factor analytic data are rotated. Finally, the resulting categorical data are used as inputs into the instructional design model creation methodology. Through the instructional design model building method, the categories of learning object design and use strategies identified in the analysis are brought into a coherent whole, as a group of methods. Along with these methods, statements of the model's overall goals, preconditions for use, and values are articulated. Finally, the goals, preconditions, values, and methods of the model are brought into a coherent form ready for peer review and publication.

4.4 Educational activities

I see research as completely integral to my teaching. While I am just beginning my position as Assistant Professor this fall (I have spent the year since graduation as a Postdoctoral Fellow under NSF DUE-0085855), my prior teaching (in Education and Computer Science) and learning experience has shown that integrating research activities into learning provides additional context and motivation that greatly enhance the effectiveness, efficiency, and appeal of education. Within the context of the project, I feel that I can positively influence a number of learners in the following ways:

- **Student apprenticeships**. Wherever possible I will involve students as research apprentices in the proposed project. This includes Ph.D. and Masters students on paid assistantships funded by the grant, as well as undergraduates potentially serving in research capacities.

- **Project as class research context**. The proposed project will also provide a research context for projects in various classes I will teach. For example, in fall 2001 I will teach a course on designing instruction using learning objects and in spring 2002 I will teach a course on qualitative research methods. The learning objects course will be centered around reviewing and critiquing existing approaches to learning object use, as well as creating exemplary models of learning objects-based instruction. The qualitative methods course will focus heavily on Wertsch's, among other interpretivist, analytical methodologies. Both courses provide natural spaces in which students can engage in research in the course of their class experience.

- **Sample framework implementations**. As the new framework takes shape, I will design portions of courses and/or entire courses around the framework as appropriate. These implementations will allow students to engage reflexively in their research as they learn within the environment they are researching.

Additionally, these implementations will provide important formative feedback to the framework development process (Wiley, 2000; Nelson, 1998).

- **Digital library of exemplary resource use cases**. As exemplary situations in which learning objects are used to mediate problem solving and other learning are discovered within the online community records, these will be stored in a digital library and annotated in light of the emerging framework. This collection will provide teachers and learners interested in various aspects of the framework to see exemplary cases of various portions of the framework in action.

4.5 Role of the advisory board
For this project I have assembled an advisory board of five members: Dr. Laurie Nelson (Indiana University), Dr. David Merrill (Utah State University), Dr. Mimi Recker (Utah State University), Dr. Brent Wilson (University of Colorado, Denver) and Dr. Marcy Driscoll (Florida State University). The advisory board will meet annually during the summers between each academic year of the grant (four times). This will provide me an opportunity to present current work, gather feedback and suggestions, and generally improve the quality of project work.

4.6 Project organization and management
I will be responsible for overseeing all aspects of the research. The staff will include three graduate students during the five years of the project. These graduate students will help with all aspects of the research, including data gathering, analysis, framework building, digital library building, publishing, and presenting research at conferences.

5. Summary
At the beginning of this proposal I asserted that the main interest in learning objects was around their ability to facilitate "anywhere anytime" learning. I argued that several organizations have attempted to meet this goal through a process of decontextualization, isolation, and automation. I then presented an example of learning objects used to facilitate learning in a real-world problem-solving environment rich with context and human interaction. I suggested that this environment is capable of scaling to extremely large numbers of learners, and has in fact already done so (the community Slashdot has over 30,000 registered users). I believe that a more rigorous understanding of the ways in which learning objects function in these existing, interaction rich communities could provide the basis for instructional strategies with the potential to revolutionize online learning. Specifically, the research will shed significant light on the role of learning objects in mediating problem solving within the information technology learning domain. Last but not least, the project will provide solid grounding to a life-long research agenda dedicated to understanding the effects and potential benefits of technology on learning.

6. Summary of research accomplishments
My prior research has included most aspects of learning objects research, including work on metadata concepts and standards (Wason & Wiley, 2000), non-authoritative metadata as a method of capturing learning objects' use contexts (Recker & Wiley, in press), metadata search interfaces and algorithms (Wiley, 1999), fundamental learning objects concepts (Wiley, South, Bassett, Nelson, Seawright, Peterson, & Monson, 1999), as well as a taxonomy of learning object types and detailed directions for their design and implementation (Wiley, 2000). My research projects have been favorably mentioned by The New York Times, MIT Technology Review, The Economist, and other news media.

My work with learning objects is widely recognized in the field of instructional design and technology. I have written a number of invited articles and chapters on the topic (Wiley, in press-b, in press-c; in press-d; Recker & Wiley, in press; Wason & Wiley, 2000), in addition to writing one of the first dissertations (Wiley, 2000) on the topic and editing the first book (Wiley, in press) about learning objects. In addition to publishing several non-invited pieces (e.g., Recker, Walker, & Wiley, in press), I am active in several professional organizations and have presented learning objects-related research at several conferences, including AERA, Internet2, AECT,

and WebNet. In 2001 I have been invited to speak or participate in panels at Internet2, ICALT, AECT, and the 13th Annual Instructional Technology Institute.

I am currently serving as the Chair of the NSF's National Science Digital Library's (NSDL) Standards Committee, where I coordinate and direct metadata and other standards work relating to the NSDL. I also Co-Chair the NSDL's Ad-Hoc User Profiles Committee with Brandon Muramatsu of The University of California, and serve on the NSDL Coordinating Committee.

Finally, in my first year out of graduate school (Summer 2000 to Summer 2001), I have received over $550,000 in grant and contract monies for learning objects research. This breaks down to approximately $428,000 from the NSF for the Instructional Architect project (with Drs. Mimi Recker and Jim Dorward; http://ia.usu.edu/), $40,000 from Utah State University's Vice President for Research for the EduCommons project (http://educommons.org/), and an $83,500 contract from the Cisco Learning Institute.

7. Results from previous NSF support

I am currently engaged in work on NSF award DUE-0085855, "The Instructional Architect: A System for Discovering, Recommending, and Combining Learning Objects" as Co-PI with Drs. Mimi Recker (PI) and Jim Dorward (Co-PI). This award was made in the amount of $428,401 for a period of two years, beginning in September of 2000. The project involves the creation of a service layer for existing digital libraries that allows resources within the libraries to be more effectively discovered and utilized. The project was spurred by interactions with NSF-funded digital libraries for educators, which provide access to high-quality resources and a simple search feature, but stop there. Because these systems do not provide users with the ability to combine and utilize resources within the system, users are forced to download resources offline, combine them by hand in an HTML editor, and republish the new collection somewhere on the web. The necessary degree of technical expertise keeps many educators from effectively utilizing the resources within the libraries.

Accordingly, we proposed the creation of (1) an online educational resource combination environment, and (2) an advanced search / collaborative filtering feature that would recommend additional resources and like-minded people to users. This set of tools allows teachers to find and utilize educational resources they discover online without programming expertise or an account on a web server. Response to early versions of the tool has been excellent; we have already integrated its functionality with the NEEDS and SMETE.ORG collections at the University of California, and the National Library of Virtual Manipulatives for Virtual Mathematics at Utah State University. We have recently begun talks with the University Center for Atmospheric Research (UCAR) regarding providing this functionality to the Digital Library for Earth System Education (DLESE).

A prototype of the Instructional Architect system is available for download, complete with source code but missing some of the proposed functionality (as we are half way through the funding cycle). Two publications describing the Instructional Architect system are also available (Recker & Wiley, 2001; Recker, Walker, & Wiley, 2000), as are white papers describing various aspects of the project, such as descriptions of user-selected metadata elements for educational resource discovery. More information is available at the project website, http://ia.usu.edu/.