

Use Scenarios in the Development of the Alexandria Digital Earth Prototype (ADEPT)

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A user-centered, iterative design philosophy requires a common language between users, designers and builders to translate user needs into buildable specifications. This paper details the rationale, evolution and implementation of use scenarios—structured narrative descriptions of envisioned system use—in the development of the Alexandria Digital Earth Prototype. This paper discusses the strengths of the scenario approach, obstacles to their use, and lessons learned in the overall development process.

Introduction

The Alexandria Digital Earth Prototype (ADEPT) uses the digital earth metaphor to organize and present geographic information at many levels of spatial and temporal resolution. Building on the Alexandria Digital Library (ADL), ADEPT is a five-year project based at the University of California, Santa Barbara (UCSB), with the education and evaluation component of the project a partnership of UCSB and the University of California, Los Angeles (UCLA). In its present stage of development,

ADEPT is envisioned as a set of tools and services for instructors, teaching assistants and students to search, save and share electronic resources from digital collections of geographic information. These resources can be used to create lecture presentations and laboratory exercises for use in undergraduate geography courses.

The ADEPT project is motivated in part by the belief that digital library services that provide instructors and students with the means to discover, manipulate and display dynamic geographical processes can contribute positively to undergraduate instruction. The range of research questions associated with this belief is detailed in Borgman et al. (2000), but relevant here are questions such as:

- How can ADEPT accommodate users with different skills, knowledge, cognitive styles and pedagogical styles?
- How can ADEPT help users view primary geographical evidence in new ways to answer scientific or geographical questions?

To answer these questions, it was first necessary to understand the range of current pedagogical practices. The first phase of ADEPT research included concurrent activities such as developing evaluation design and instruments, identifying geography courses and user groups, pedagogical goals and styles of course instructors, and establishing design principles for the development of the ADEPT system. ADEPT researchers undertook an iterative, user-centered approach that called for interviews with faculty and students, videotaped classroom observations and content analysis of the textbooks, laboratory exercises and exams used in undergraduate geography courses to ground and evaluate initial assumptions embodied in the design principles. The observation of undergraduate classrooms has taken place over the last three years, on both campuses. Geography instructors were consulted to help solidify, debunk, enhance or prioritize initial conceptions of ADEPT services, and how ADEPT would be used in the classroom.

The interviews with faculty and students yielded a deep understanding of practices for undergraduate geography instruction. Initial results suggested that it will be a challenge to match the content and functionality of ADEPT to the range of instructors' pedagogical styles. Variations in instructor teaching experience, technological expertise and preferences, and physical infrastructure of classrooms all introduce obstacles to a one-system-fits-all ideal. However, on the whole instructors were enthusiastic about the possibilities of the new technology and were willing to venture outside their comfort zones to participate in ADEPT development and evaluation. Similarly, in identifying user groups it became clear that teaching assistants played a larger role than previously thought, and that in the context of an ADEPT-based laboratory exercise, students would have a different set of interactions with the system than either instructors or teaching assistants.

It then became the task of the various ADEPT system designers to translate the understanding of instructional practices into succinct expressions of user needs which in turn could be translated into buildable specifications. A first effort of this translation yielded a set of design principles. These development and use of these design principles are described in the following section. Subsequent iterations of design work concentrated on the development of use scenarios to provide further articulation of anticipated system use. The bulk of this paper details how use scenarios—structured narrative descriptions of envisioned system use—have served that purpose. In the development of ADEPT, use scenarios link bottom-up needs analysis from users with top-down abstract design principles, and serve as a common language between users, designers/evaluators and builders.

Evolution of the ADEPT Design Principles

The earliest interviews with undergraduate instructors and students yielded a set of design principles (Gilliland-Swetland & Leazer, 2001). These design principles formed the earliest set of assumptions about how the system would be used, and were the first step toward representing user needs and creating functional requirements. The design principles included:

- *Transparency*
- *Diversity and extensibility of metadata*
- *Progressive skill-building*
- *Authentic science topics*
- *Parameter variation*
- *Appropriate use of technology*
- *Scaffolding*
- *Hybrid collections*

The design principles were refined and evaluated in a subsequent round of interviews. These interviews resulted in valuable feedback, collected in time to serve as input to ongoing ADEPT development. For example, the *Transparency* design principle states that “the technology to development and use learning modules should not intrude upon developing and learning content, concepts, and processes” (Gilliland-Swetland & Leazer, 2001). In an in-depth interview, one instructor confirmed that 30 minutes was a realistic maximum for students to be expected to invest in learning to use ADEPT, but thought that faculty could be expected to invest more time. The *Transparency* design principle was modified to reflect these observations.

Even among instructors, motivation to learn and use ADEPT, both in course preparation and in lecture presentations, varied well beyond any single image of an ideal user. One instructor was focused on research and publication, and wished to invest as little time as possible in using ADEPT to prepare for an undergraduate course, while another instructor was openly excited about the possibilities of the technology. To represent expected use, a more refined picture of the range of potential users and their actions was needed as input to the development of the system as it emerged from these interviews.

Though the design principles document served a useful role in clarifying the focus and scope of development and evaluation efforts, the builders of the ADEPT system felt that the design principles alone were too brief and vague to be made into formal functional requirements. The design principles were viewed as a “top-down” mode of design that did not contain enough articulation of system functionality for the designers to proceed with

development. A layer of translation between design principles and functional requirements was necessary, one that provided descriptions of user motivations and context through narrative descriptions of envisioned use. Thus the ADEPT education and evaluation team embarked on creating a set of user scenarios to provide a greater articulation of imagined system use to system developers.

Use Scenarios in Digital Library Development

Use scenarios are narrative descriptions of envisioned system use, “listing the various steps a user would take to perform a sample set of realistic tasks” (Nielsen, 2001). They have been conceptualized as “requirements in context” (Kulak & Guiney, 2001), and have been used to support design strategies focusing on user responsibilities (Wirfs-Brock, 1995), roles (Renouf & Henderson-Sellers, 1996), priorities (McGregor & Major, 2000) and goals (Cockburn, 1997; Lee & Xue, 1999).

Use scenarios document “typical and significant” user activities as early and continuing input to the development process (Carroll, 1994), and are designed to be understandable to users, who might interact with them in participatory design projects. They have long been used tacitly in system design but only recently have become more formalized. A more technical “use case” approach was brought to prominence by Jacobson et al. (1992), although many competing definitions of the term have been spawned—Cockburn (1997) identifies eighteen distinct variations. In his distillation and analysis, he writes that any use scenario should contain the following information:

1. Primary actor
2. Goal
3. Conditions under which scenario occurs
4. Scenario result (goal delivery or failure)

Larman (1998) makes a useful distinction between “essential use cases” (Constantine, 1995), an abstract form free of technological or design detail, and “real use cases,” which describe use in concrete terms and do include specific design decisions and technologies. Essential use cases are the ideal type in a strongly user-centered environment, though the realities of system development often either openly or tacitly constrain their expression.

Methods for the development of use scenarios require that the goals and needs of potential ADEPT users be determined in detail, with the understanding that these goals and needs will evolve over time. Since this has been the focus of the ADEPT data collection effort from the beginning, use scenarios are a natural choice. The multi-method ADEPT approach blends “top-down” design principles and best practices with “bottom-up” input from potential users in real-world situations. Marchionini,

Plaisant and Komlodi (2001) also advocate a multifaceted approach to identifying users’ information needs, characteristics and contexts in their assessment of the Library of Congress National Digital Library Program:

“All efforts to design, implement, and evaluate digital libraries must be rooted in the information needs, characteristics, and contexts of the people who will or may use those libraries.”

The authors break this general guideline into three main points:

- understand user characteristics and needs
- develop the digital library iteratively, as user characteristics and needs change
- anticipate and accommodate diverse use strategies

Both use cases and use scenarios have been employed in previous digital library development projects. The Digital Library for Earth System Education (DLESE) is a community-developed resource providing searchable access to collections of high-quality educational resources for the geosciences (Marlino & Sumner, 2001). As a collaborative effort, DLESE has employed user-centered and participatory-design methodologies, including use scenarios written by educators and derived from interviews with prospective users (Wright, Marlino & Sumner, 2002; Davis & Dawe, 2001). The benefits of use scenarios for DLESE have been to formalize user needs and to serve as evolving platforms for ongoing formative evaluation, which illustrates the usefulness of the scenario approach in the analysis phase as well as the design phase.

Since a primary focus of the ADEPT education and evaluation effort is formative evaluation, requiring a deep understanding of user needs and capabilities at every step through the system’s various functions, we have chosen to follow the DLESE user interface development methodology (DLESE, 2002), and focus on creating use scenarios with a task orientation.

Use Scenarios in ADEPT

First-generation Scenarios

Initial data collection in the first years of ADEPT research focused on requirements analysis, evaluation design and pilot testing. The choice to make use scenarios a more formal part of the development process occurred late in the second year of the project. Following the design principle that the digital library system should illustrate dynamic processes and be grounded in actual use, geography instructors were interviewed to develop

consensus on canonical introductory topics that would be good candidates for illustration in ADEPT via use scenarios. This consensus approach resulted in four topics: erosion, plate tectonics, disease vectors and von Thunen models of agricultural land use. Since the initial testbed was physical geography courses, fluvial geomorphology (the work of rivers and streams, including erosion) was chosen to focus initial system and collection development efforts. Having students learn about fluvial processes became a goal for the first set of use scenarios.

ADEPT researchers wrote scenarios based on data gathered in the initial two years of the project (Leazer et al., 2000; Borgman et al., 2001), though a layer of iteration was built in to allow for feedback from potential users. Each scenario was accompanied by an associated sample digital resource and presented to a geography instructor for evaluation in an open-ended, in-depth interview. The results were somewhat surprising in the amount of emphasis put on ease of use rather than complex functionality. This concern with saving time was reflected in this first-generation use scenario (Table 1), and shows how user feedback informs design.

Table 1. First-generation Use Scenario Excerpt

Actor: *a climatology professor*

Setting: *[Instructor's] home office.*

Goal: *She wants to update her lesson plans to include more active exercises to engage the undergraduates. She's anxious to get this instructional preparation work done because she wants to return to her research.*

Scenario: *She opens the ADEPT digital library and scans the screen for something that can help her get started. She clicks ISCAPES. A window pops up with an explanation: "An ISCAPE is an information landscape that includes tools and services for expressing and visualizing geo-spatial concepts and processes. Users of ADEPT employ ISCAPES for building customized research or instruction environments. See HOW TO USE ADEPT for more information." She ignores the link. She doesn't have time to read instructions.*

Other first-generation use scenarios varied widely in content and structure. Some gave little or no mention of the interface, others lacked any discussion of the user's context or situation and were little more than bulleted lists of actions in sequence. Following Cockburn's actor-goal-conditions-scenario model, in each case the actor was an instructor seeking to create a lecture presentation or laboratory exercise by searching, evaluating and compiling a group of digital resources germane to the topic.

Having students learn about each of the fluvial processes subtopics served as the goal in separate use scenarios. How to imagine and state the system functionality to achieve these goals, however, was the source of widely varying

interpretations by the researchers. And perhaps this was to be expected; where the DLESE project has a roster of use case experts with a job description specifically for this task, ADEPT use scenarios were written by researchers from both the UCSB and UCLA campuses, each with a variety of research backgrounds and subject expertise, including geography, computer science, information studies, and psychology.

Though each of the first-generation use scenarios reflected user needs and projected system capabilities into a structured narrative, in order to transform these scenarios into buildable specifications, a more formal approach was required.

The Use Scenario Cookbook

After a joint meeting of UCSB and UCLA researchers, designers and system builders, it was decided that a use scenario "cookbook" be drafted (Table 2), so that existing scenarios could be refined, and future scenarios created, in a more formal manner. Cockburn's four-element actor-goal-conditions-scenario model was tightened to focus on specific system functions and collections wherever possible, to give the system builders more concrete descriptions of imagined use.

Though the cookbook essentially served as the operationalization of use scenarios in ADEPT, to accommodate the diverse perspectives of different designers and users, the cookbook was envisioned as a set of high-level guidelines rather than rigid rules, which is reflected in the variations in the structure of some of the scenario excerpts below.

The cookbook was circulated to all ADEPT project members involved in writing the scenarios. It provided a structured way to separate users' roles from their goals, and to provide realistic contexts for their actions. In many cases, this approach led to more detailed discussion and analysis of the tasks the system should support.

Table 2. Use Scenario Cookbook Excerpt

1. Scenario scope

Scenarios should be written from the user's perspective, and specify what interactions the system should support. Assumptions made about the user's context, tasks and stepwise behavior within the scenarios should be grounded in reality (e.g. interviews with users) whenever possible. The scenario should be limited to describing one interaction with the system, which will usually consist of a set of dozen or so related functions and actions. Each scenario should include:

- *One or more geographic concepts*
- *Hypotheses related to these concepts*
- *Instructional goals*

2. Writing scenarios

Scenarios should follow a four-element model:

- Actor (instructor, TA, student)
- Goal
- System function
- Resource (collection)

Describe the interaction as simply as possible, focusing on the goals and experience of the user at each step. Avoid references to specific software or interface elements; this leaves open the possibility of considering a wider variety of solutions. Resist the temptation to make design decisions—scenarios inform design, not dictate it. Include references to all relevant aspects of the interaction, even cultural and environmental issues that may expose areas of weakness in the system's real world implementation.

With this more focused cookbook, face-to-face meetings between researchers from both campuses, and more input from ongoing user needs analysis, the second generation of scenarios served to both refine the expression of realistic use situations and to provide a level of detail that could result in buildable specifications.

Second-generation Scenarios

Apart from the more formal structure brought about by a shared cookbook and intensified group feedback, the second-generation use scenarios also explicitly reflected a wider variety of primary actors (instructors, teaching assistants and students) as imagined users. In the first classroom evaluation of an early ADEPT prototype (Borgman et al., 2000), the instructor largely delegated the creation of a lecture presentation to a teaching assistant. The instructor selected, evaluated and organized the presentation only after the teaching assistant had created the initial rough cut and populated it with digital resources. This suggests that teaching assistants—not instructors or students—may turn out to be primary users of the final system, so successive generations of use scenarios have included some with a teaching assistant as the primary actor.

In laboratory sections, teaching assistants give brief review presentations and must assess students' level of understanding from week to week. Additionally, regular interactions between instructors and teaching assistants may occur, including discussions about how course information is communicated to students and which concepts are giving students difficulty. Canonical use scenarios generally portray a solitary actor, but this

artificially eliminates multi-actor interactions where goals and tasks are negotiated.

An excerpt from a second-generation use scenario (Table 3) illustrates this more social perspective, as well as boundary interactions with communication and reporting systems.

Table 3: Second-generation Use Scenario Excerpt

Actor: Physical Geography Teaching Assistant (TA)
Goal: Create and administer a laboratory exercise for introductory geography students on the rain shadow effect
Conditions: TA will administer the lab exercise after the corresponding lecture.

Scenario: TA assumes that the students know what the rain shadow effect is (that precipitation amounts drop significantly on the leeward side of a mountain). However, since this is an introductory class and the rain shadow effect is complex, she chooses to construct a simple exercise where students 1) Identify the important variables associated with rain shadows and 2) Identify the equipment necessary to measure these variables

TA logs on to ADEPT from home. Since she has used ADEPT before, the course and instructor appear as defaults. Following the course topography (an outline of the course content similar to a concept map), TA selects the Rainfall section and a list of materials selected by the instructor appear, broken down by subtopic. She selects rain shadows and finds a topographical map with associated rainfall and wind velocity data for a given storm.

She creates a new interaction on the ADEPT menu. She drags and drops the topographical map, rainfall and wind speed data into this interaction. She decides that students might need a brief opening refresher on the topic, so she drags the rain shadow image the instructor used in lecture into the interaction as well.

She wishes to use this image to ask students which set of three instruments would be needed to gather data to measure the rain shadow effect (rain gauges, wind speed gauges, topographical map).

For the next set of screens, given data on two of these variables (rainfall, wind speed, elevation), she asks students to make conclusions about the third.

TA saves the interaction and alerts the instructor via e-mail. The instructor runs through the interaction and offers a pointer to more relevant data from his personal collection, to which he provides a link. TA retrieves this item, saves it to her hard drive, then logs into ADEPT and imports the item into the interaction.

In the laboratory section, students log on and work through the interaction.

TA monitors students' progress from her own terminal and checks that the exercises have been completed. Questions that many students answered incorrectly are flagged and

the TA chooses to inform the instructor that it might be worthwhile to review these areas in the following lecture.

The second-generation scenarios were merged onto a Web page so researchers from both campuses could provide feedback, then an in-person workshop was convened where the revised scenarios were discussed. Common classes of user needs and associated functionality emerged, and a use scenario based on river networks was selected as an exemplar to focus development of the running prototype.

Student-centered Scenarios and Educational Outcomes

Several of the second-generation scenarios focused on the goals and activities of students. These were created to guide the design of modules to teach both specific content knowledge and scientific reasoning skills.

These scenarios differed from the instructor and teaching assistant scenarios in two important ways. First, the instructors and teaching assistants are assumed to have sufficient knowledge to accomplish the task. That is, they know how to create lectures and use images to teach concepts, but they do not know how to use ADEPT to do so. Students, on the other hand, will lack both the skill to perform scientific reasoning and the skill of using the ADEPT interface. Second, there is an existing psychological literature on scientific reasoning that describes both how students should perform a scientific reasoning task and how they can be expected to perform the task. This literature, therefore, was used to develop descriptions of students' activities, goals and expected problems.

Scientific reasoning is the process of systematically using information to create and test theories. It is, within the rubric of Western science, broken into four steps. The first step is to select a hypothesis to test, based on observation of the world. The second step is to select data to test that hypothesis. The third step is to interpret that data, to decide whether it supports the hypothesis or not. The fourth step is to draw conclusions about the hypothesis based on the data. In addition, there are logical and practical rules that govern each step, such as that hypotheses should be parsimonious, consistent, and testable.

Each of these subtasks implies functionality that should exist in the system. For example, if students need to create hypotheses to test, they will need some kind of background information first, to suggest possible hypotheses.

In addition to normative models, the research literature also describes the errors that students are likely to make in scientific reasoning. Since one of the goals of the system is to develop scientific reasoning skills, students may require

support to avoid these errors. For example, Wason (1960), and Dunbar (1993) both discuss a phenomenon called "Confirmation Bias." This refers to people's tendency to choose data that cannot test their hypothesis, but rather only support the hypothesis. Dunbar (1993) suggests that this bias results from students having the goal of supporting their hypothesis rather than creating and testing multiple hypotheses. This suggests that students may need assistance in creating hypotheses and choosing their data. Likewise, students have been shown to fail to complete tests due to breakdown in "metastrategy" (Kuhn, Garcia-Mila, Zohar, & Anderson, 1995), that is, a failure to plan and monitor their activities. This suggests that students will benefit from planning tools and a log of their activities.

To address these issues of possible errors in scientific reasoning, and to assess responses to different levels of assistance by the system, several student-centered scenarios, such as the one excerpted in Table 4, were created. In accordance with the ADEPT design principles, this scenario also illustrates how the system could be used to create templates for classroom laboratory exercises that address actual scientific problems, involve progressive skill-building and educational scaffolding, and are simultaneously challenging, effective, and easy to navigate and complete.

Table 4. Student-centered Use Scenario Excerpt

<p>Actor: <i>student (S)</i></p> <p>Setting: <i>Laboratory section classroom.</i></p> <p>Goal: <i>Determine the cause of the Nile River Delta filling with salt water.</i></p> <p>Scenario: <i>S searches for preliminary information about the Nile River Delta, to get some background on the topic. The preliminary information gives her several hypotheses, such as that global warming is causing sea levels to rise, and that the Aswan Dam upstream is lowering the river levels.</i></p> <p><i>S decides to test the hypothesis that global warming is melting the polar icecaps, causing the oceans to rise. This is, in turn, causing the Mediterranean Sea to rise and flood the river delta. Her current goal is to find evidence for global warming.</i></p> <p><i>The system, given her choice of hypothesis, suggests that she test sea levels across time. She is given some choice of what locations around the sea to test, and given a list of data to look at. In looking through the list, she can see that they are not the cause of the flooding.</i></p> <p><i>After she has tested this hypothesis, the system lets her know that she should test her other hypotheses, rather than continuing to focus on a disproved theory.</i></p> <p><i>S decides to test a new hypothesis.</i></p>
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Use Scenarios as Input to Prototype Development

Once the scenarios have been created, refined and prioritized, there remains the matter of turning them into actual software. However, scenarios were not the only, or even the primary, mode of prototype development in ADEPT. Software engineers needed to hybridize a diverse set of thought processes and work strategies, which caused tensions of varying degrees to arise.

Different software engineers bring very different backgrounds, interests and expertise to a given project. What may be less apparent to those outside the field is that they have different work styles, practices and philosophies as well. Each tends to prefer familiar work processes and approaches to problem solving and may be more or less receptive to outwardly-imposed structures like use scenarios.

There was some tension between scenario-based development, where expressions of user needs and actions are given primacy, and what one ADEPT software engineer called prototype-based development, which begins with an engineer's initial build and gets iterated toward usability. In a presentation to the Joint Conference on Digital Libraries, one of the ADEPT software engineers characterized the scenario effort as just one stage within a larger system development framework:

“The development process for these applications is a hybrid of standard iterative user centered design and the kind of small and fast development described by Verplank's spiral or the futurist programming manifesto. The current stage of the process involves the development of scenarios and general feature descriptions (as captured by the E&E team) into screenshot proposals, cognitive walkthroughs and mockups into small but functional applications.”
(Ancona & Smith, 2002)

The above quote illustrates that in practice, ADEPT software engineers viewed use scenarios as one of many approaches, alternately emphasized and de-emphasized with the changing demands of the project. The use scenario effort was characterized as usability work, as opposed to the work of generating functional code. Deadlines often required software engineers to provide a workable solution now and worry about usability issues later.

The influence of spontaneous connection—serendipity—deserves at least passing mention. While the planned evolution of the scenarios did make them more specific and more tightly focused on functionality, the use scenario process did not bear fruit for one software engineer until he read a document which he described as an ‘eight-step path’ through the various functions of the system. This was the breakthrough that made the scenarios ‘click’ for him, but ironically, this document was not part of the scenario process but a separate document submitted to the human subjects review board. This personal ‘aha! moment’ led to a version of *geoflow*, a functional mockup of the integrated ADEPT lecture development environment that took into account scenarios of how instructors might use ADEPT.

Similarly, when software engineers ‘just happened’ to be familiar with a piece of proprietary, off-the-shelf or open-source software that could be used to solve a problem, this sometimes drove the development of the associated ADEPT components. One engineer reported having some ‘code laying around’ which he used to create *sproing*, a tool for concept space visualization.

This situation recalls the continuum between essential (abstract, user-oriented) and real (concrete, system-oriented) use cases, and reflects how tacit constraints often account for the difference between the system imagined and the system built. Anticipating these issues, and making a user-oriented, scenario-based approach a priority from the earliest phases of a project, is essential for the use scenario approach to have maximum impact.

Conclusion and Lessons Learned

In sum, employing use scenarios in the development of ADEPT has led to the following suggestions and lessons learned:

- Use scenarios can serve as a common language between users, designers and builders, and can be an effective way to give user needs primacy in the development process.
- Use scenarios are effective tools for system evaluation and analysis, not just initial design.
- Formalization of the use scenario creation process—even with a brief, high-level document like the use scenario cookbook—can result in more focused expressions of user needs and system requirements, and make it easier for a wider range of individuals to contribute their perspectives to the design process.
- Comparing classes of user and system behaviors across many use scenarios can identify design priorities and reduce duplication of effort.
- Roles are not goals: Separating the actor from the activity can yield productive insights into system

design. This approach has resulted in the identification of useful hybrids that better reflect real world behavior, such as instructor-as-searcher and teaching assistant-as-instructor.

- Use scenarios document the iterative design process and reflect the results of the ongoing needs analysis. Scenarios can be used as a focused introduction to the history and progress of ADEPT development, and help bring new project members up to speed quickly.
- To represent user needs most effectively, the use scenario approach should be organic to the entire development process.

Use scenarios are designed to evolve with each phase of new information as user tasks, goals and activities are identified. Current data collection is focusing on a usability study of the latest prototype, which will likely reveal the breadth of user needs, information searching styles and resource evaluation strategies in finer detail, continuing the iterative design process.

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