TRAILS Y4 Annual Report

September 2005 – August 2006

"Working across disciplines, I got to experience a part of what real educational software designers do... In the process, I got to learn a ton about real-life software design, work with teachers and kids on building a great product, and meet lots of cool people to bounce ideas off of and collaborate with."

— Ankur Dalal, a computer science major in a TRAILS course at Stanford University in 2004

Introduction

TRAILS aims to broaden and support the pool of talent available to create powerful technology for K-12 education, such as simulations, adaptive tutorials, interactive exhibits, and educational games. Our approach focuses on engaging teams of university students in the creation of educational technology through project-based design courses. Through these courses, TRAILS intends to have three major effects: to better prepare tomorrow's designers of educational tools, to better prepare the teachers who will use such tools, and—by publishing selected course projects—to generate new tools for K-12 education.

We had a busy and productive fourth year of the TRAILS project, the last official year of our grant. The dominant theme of the year was focusing our efforts on dissemination and ensuring the project's legacy. We accomplished the following:

1. Organized a book on learning about learning technology design tentatively titled "Educating New Generations of Learning Technology Designers."
2. Designed a new interactive public Web site, Learning about Learning Technology Design (L^2TD), which will complement the book.

Three TRAILS-affiliated courses were taught in the fall and winter:

3. "Designing Educational Technologies" at Penn State University
4. "Collaborative Design and Research of Technology-Integrated Curricula" at Stanford University
5. "Gamelet Design for Education" at the University of Colorado at Boulder (CU).

All three of these courses benefited from the fact that they were in their second, third or fourth iteration by this time, with a well-refined syllabus, experienced teaching assistants, and a library of previous projects readily available to students.

At the end of Y4, we received a no-cost extension to the TRAILS project, which will allow our dissemination and outreach activities to continue until 31 August, 2007.

Activities

What have been your major research and education activities (experiments, observations, simulations, presentations, etc.)?

Below we list our major activities over the past year in the following categories: Dissemination, University Education, Evaluation, Collaborative Software Design, and K-12 Classroom Impact. We follow that with more details about work done at individual partner sites.

Dissemination Activities

Book Writing. In our summer biannual meeting in August 2005 we agreed to focus our dissemination efforts on a book oriented towards instructors of learning technology design, which we tentatively titled "Educating New Generations of Learning Technology Designers." In a subsequent winter meeting we developed a detailed table of contents, gathered abstracts from over 20 contributors, and identified four possible publishers. A completely new chapter emerged during this meeting, based on an impromptu round-table discussion on the challenges of teaching multidisciplinary courses that we audio taped and transcribed.

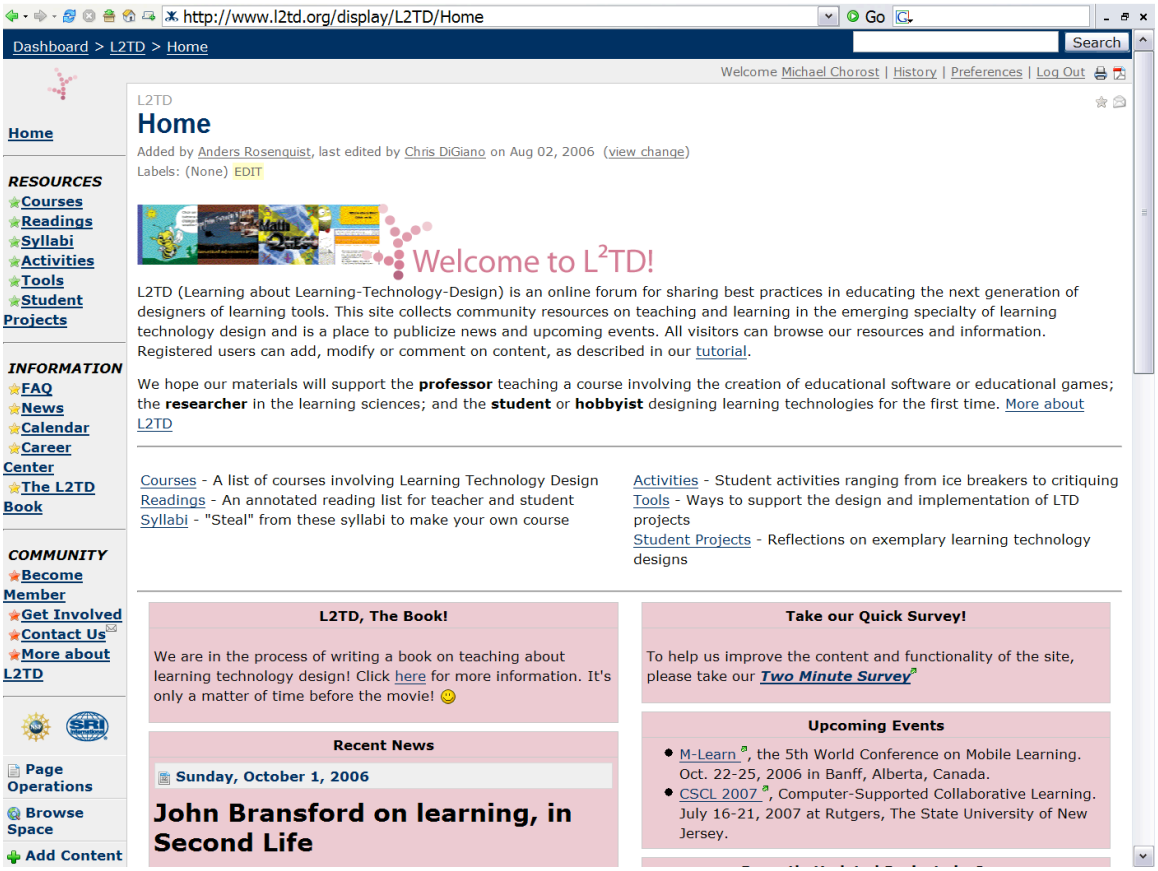
Below we list a few chapters to give a flavor of the book's contents:

- "The Case for Preparing the Next Generation of Learning Technology Developers"
- "Collaborating to Learn, Learning to Collaborate: Finding the Balance in a Cross-Disciplinary Design Course"
- "Running Design Studios for Educational Technologists"

We received positive responses to our book proposal from Lawrence Erlbaum and Springer Verlag, both with stellar reputations in publishing books on education and technology. After due consideration of offers from both, we chose to go with Erlbaum. To show publishers the extent of our potential audience, we compiled a list of 29 courses in learning technology design (LTD) and posted it on our internal wiki. This list is also likely to become a valued resource for instructors seeking inspiration from other institutions.

Through the book development process, we were pleased to establish ties with Sally Fincher, the lead author of an important book in the computer science education field, *Computer Science Project Work: Principles and Practices* (Springer, 2001.) In our August 2005 meeting, Dr. Fincher helped us identify core ideas for our book and made numerous helpful suggestions. We hope to entice her to write a preface for our volume.

Public Web Site. We used Y4 of TRAILS to migrate and extend online resources to a new Web site, which has a Wiki infrastructure that allows community contributions. Given that the project is coming to an end, we have gone to great lengths to "debrand" our content before transferring it to the new site. In fact, the site is not called "TRAILS" but "Learning about Learning Technology Design (L^2TD)". The "squared" refers to the fact that LTD courses teach students how to create tools that teach – in other words, the field is meta-teaching. The site went live in July 2006. Below is a recent snapshot of the front page:



University Education Activities

In Y4 of TRAILS, 30 university students participated in TRAILS-affiliated courses at 3 institutions. 40% were female and 53% were graduate students. The following table shows each course's breakdown by gender and status.

	CU Boulder	Penn State	Stanford	Total
Course Title	Gamelet Design for Education	Designing Educational Technologies	Collaborative Design and Research of Technology-Integrated Curricula	
Female Students	4	3	5	12
Male Students	10	4	4	18
Total Students	14	7	9	30
Graduate Students	1	7	8	16

As in Y3 of TRAILS, each of the courses used a mixture of instructional techniques and activities, including lectures, discussions of readings, opportunities for group work, reviews of existing educational technologies, and presentations by guest speakers. The courses required students to use journals to capture design ideas and reflect on the readings.

Evaluation Activities

Our evaluation efforts were refocused after our pre-post survey in Y3 yielded relatively little information of novel interest. We rewrote the survey so that instead it assessed the degree to which students conceptualized and solved problems similarly to experienced professionals. We administered it to the Stanford and CU courses at the end of the term and have conducted a first-pass analysis the responses. These are described in the Findings section.

The new survey design was inspired by Shulman's 3-part notion of professional apprenticeship[1], which emphasizes the need for newcomers to learn not just the practical skills of a trade but its cognitive and moral traditions as well. To assess these aspects of apprenticeship in the field of learning technology design, we devised a three-part survey. In Part 1 respondents were asked to react to 2 out of 4 design scenarios that emphasized the practice of learning technology design. For example, the first scenario invited students to submit a written reply to the following question:

> You're on a team developing an environmental science curriculum for middle school students. Some members of the team think students should have the same datasets and visualization tools that scientists do to enhance authenticity, but others think that real datasets can be too messy for classroom use. How would you resolve differences in opinion within the team?

In Part 2, respondents were asked to answer 3 value-related items. The first was about the variety of stakeholders of educational applications. The second concerned limits to responding to stakeholder input. The third asked respondents to position themselves by answering 7 paired statements, of which two are shown below:

c. When I design, I believe it is important to…

Create detailed requirements (specs) before building				Continually revisit requirements (specs) during building
1	2	3	4	5

f. I feel my job is done when…

My aspect of the task is finished and tested				All materials are complete (.e.g., technology, curriculum, and activities)
1	2	3	4	5

In Part 3, study participants were asked to respond to an item intended to evaluate their conceptualization of the learning technology design profession. They were asked to draw a concept map of major design issues, using a model map of user-centered design as a starting point.

[1] Shulman, L. (2005). The Signature Pedagogies of the Professions of Law, Medicine, Engineering, and the Clergy: Potential Lessons for the Education of Teachers. Delivered at the Math Science Partnership (MSP) Workshop: "Teacher Education for Effective Teaching and Learning" Hosted by the National Research Council's Center for Education. Irvine, California.

We administered the survey to 12 TRAILS students and to 5 learning technology design professionals selected from the Center for Technology in Learning at SRI.

Collaborative Software Design Activities

The Gallery, Organizer and Repository of Projects (Gorp), a centerpiece of the TRAILS project, continued its mission of providing a repository of student projects. We made substantial upgrades to its functionality and interface. New features were added that allow instructors to create "tags" for projects so that students can indicate, say, the name of the assignment associated with their current project. Applets can now be launched directly from each project's overview page. An RSS feed is available so that other Web sites can list recently changed projects with links. The new L^2TD site uses this feature to show Gorp projects on its home page.

A major new feature is self-service support for an instructor wanting to register his or her own course in Gorp. This included adding the ability to adopt fields and categories from model courses or to devise a completely new schema as appropriate for their course. Previously, this all had to be done behind the scenes by our programmers. This new feature was developed in anticipation of the conclusion of the TRAILS project.

K-12 Classroom Impact Activities

At Drexel, Suzanne Alejandre used Gorp for a course she teaches on-line at the Math Forum @ Drexel. It's offered to teachers who act as "clients" or advisors for TRAILS student projects, and focuses on how to give constructive and pointed feedback. She created a course within Gorp and customized it so that people taking her course could practice giving feedback on real student projects. She ran two training sessions for teachers that had been recruited to comment on Stanford and Colorado's projects.

More Activities at Stanford University

Stanford again revised its TRAILS course design for winter 2006, based on observations and interview data from the previous course. The course continued to expand its focus on partner educators and field testing. As an example of the course's focus on field testing, take, the project titled "A Closer Look at Earth, from Space". The TRAILS students visited Kennedy Middle School in Redwood City to conduct field testing on six 6th graders using a paper prototype of their project. According to the team,

> The students worked in groups of three using a refined, and much sturdier, version of our paper prototype. The image strips were glued onto cardboard strips so they could be easily moved around, and green sleeves that could slip over the top half of the strips were provided to simulate the Southern Hemisphere ordering element of Seasons...The students enjoyed Seasons much more than we had anticipated. They enjoyed the challenging 'puzzle-like' aspect of it.

The course's three final projects were quite varied:

1. "A Closer Look at Earth, from Space" was designed for 4th through 8th-grade students. It was designed to precede a field trip to the Tech Museum in San Jose, but can be used independently. It offers two activities. In "Seasons", students infer that the seasons are opposite in the northern

and southern hemispheres by examining high-resolution satellite images of the earth during different months of the year. For example, they use evidence such as snow cover and vegetation to decide which images represent which seasons. In "Scavenger Hunt", students are guided by a worksheet to search for specific areas of the earth by panning and zooming into a high resolution map. A sample worksheet question is, "Find an island that looks like an animal. Which animal? Where is the island?"

2. The "Algebra Quadratic Equations Project" was designed for Algebra I students to understand the need for quadratic equations by demonstrating a problem - in this case, computing the size of a picture frame - and showing how an equation can be constructed to solve it. The curriculet consists of a sequence of mini-activities, including warm-up (offline), computer-based interactions (online), culminating lecture (offline), and classwork/homework session (offline). It was iteratively designed, incorporating feedback from a partner educator, classroom peers, class alumni, and the professor, and was field tested with students at the San Jose High Academy. The partner educator, who was present in class, noted that students enjoyed the visualization. It was especially helpful to students who normally struggle with the concepts of area and quadratic equations.

3. "Bee Smart About Weather" was designed for second graders to understand how temperature, moisture, and wind combine to create weather effects. For example, students can be directed to answer questions such as, "Set the wind to 0 and the moisture to 2 (medium). Now play with the temperature. At what temperature does the rain turn into snow?" The project was field tested at a local elementary school. Most noteworthy about this project was how they utilized multiple media. The curriculet was built using AgentSheets and supporting materials include paper worksheets. At the partner educator's request, they made the curriculet cross-curricular by having the students do writing tasks as well. The partner educator praised the project and was enthusiastic about using it again.

More Activities at the University of Colorado at Boulder

CU-Boulder enhanced its focus on field testing educational "gamelets" by working with a local middle school. Class discussions included topics such as overcoming "science apathy", facilitating collective learning in the classroom, and the role of games in the classroom. Both the CU and Stanford courses leveraged their past experience in locating K-12 teachers to give feedback on student projects by having teachers take using the aforementioned Math Forum@Drexel course in giving constructive feedback.

The Computer Science Department focused on using AgentSheets to build applications that displayed complex behavior based on sophisticated mathematical models of behavior in the real world. Alex and Clayton's students explored using sophisticated game-AI algorithms with instructional value kept uppermost in mind. In a PowerPoint slide Alex explained to his students, "In the past we feel students made an early commitment and stayed with bad ideas... we want students to respond to critiques, abandon bad ideas, and develop better ones." With that in mind, they invited their students to report their findings as "successes" or "instructive failures." The students created a profusion of AgentSheets-based games: in one week they explored collaborative diffusion, which is suited for complex, multi-agent games where path-seeking, flocking, and emergence are important. In another week they explored "segregation", which is a

variant of collaborative diffusion that enables the representation of crowd dynamics more accurately.

One student project, called “Genetic Life”, was an example of a project based on this concept. The student described the applet as follows: "The game area consists of an experimental area where the player can test their creature and a lab area where they can create new creatures based on previous creatures. Each creature has a stomach size of five and employs a particular strategy for finding food in its environment based on its genome. When a creature's stomach reserves are exhausted and it cannot find any more food nearby, it dies. The major objective of the game is to build a creature with the best possible search strategy by taking ‘fit’ creatures that survived well and combining them with the DNA of other creatures." In short, the project simulated not just creature *behavior* but creature *evolution*.

Another student explained her application, “Society”, in terms of cellular dynamics: “The world has some happy people and sad people. The feeling of people can be affected by their surroundings. If a sad person is rounded by many happy persons, he will become happy. A happy person can also becomes sad if there are many sad people nearby. A clown has more power to make sad people happy. You can select the happy people and change them to clowns. The goal is to make all sad people happy.”

Alex and Clayton made extensive use of examples of innovative projects to demonstrate new ideas to their students. They devoted considerable class time to examining “Mr. Vetro,” a learning tool in which groups of students are charged with maintaining a simulated human being's body parts (heart, lungs, etc.) Each group controls an organ using a wireless handheld and can see how their decisions affect Mr. Vetro’s health. The simulation is collective in that the teams must communicate between themselves in order to keep Mr. Vetro going.

Alex Repenning and Clayton Lewis were invited to list their 2006 course as part of CU's ATLAS (Alliance for Technology, Learning, and Society) Institute program. The ATLAS Institute is a campus-wide catalyst for multidisciplinary curricula, research, and outreach involving the content and tools of information technology. The listing was good news because it demonstrated that TRAILS courses are becoming regular university-sanctioned offerings, as well as being perceived as compatible with special certification programs like ATLAS.

More Activities at Penn State University

In the fall of 2005, Penn State University offered a TRAILS-inspired course of Y4 entitled “Designing Educational Technologies.” This was a derivative of the original Penn State course offered in Spring 2005 under a TRAILS seed grant. In this iteration, the course was co-taught with Yael Kali at Technion and Marcia Linn and Mike Clancy at UC-Berkeley. In addition to the TRAILS affiliation, this course was sponsored by the Technology-Enhanced Learning in Science (TELS) center, a research consortium funded by a $10 million grant from the National Science Foundation.

Other Activities

Suzanne Alejandre of Drexel discussed the MathTools library with Shelley Goldman's class via videoconference. Suzanne made up a web page as a prop for the presentation, and also captured her talk on streaming video.

Chris DiGiano submitted a $200K proposal to NSF for a 2-year supplement to TRAILS called Designers & Implementers of Girls' IT (Dig-IT!). Dig-IT is envisioned as a support system for college women working on projects that involve girls' IT. Support mechanisms will include a weekly face-to-face meeting, a blog circle, and an online resource center.

Findings

What are your major findings from the activities identified above?

Below we describe two key findings from Y4 of TRAILS:

1. For students, working in collaborative groups is not always an optimal strategy for success.
2. Design students need to learn to think about projects as open-ended, complex, iterative challenges rather than closed-ended ones admitting of single solutions.

For students, working in collaborative groups is not always an optimal strategy for success

Somewhat to their surprise, instructors at CU found that the Y4 projects carried out by individuals were comparable to the projects produced in teams of up to 5 students in previous versions of the course. Consistent with the students' own perception that group work is a lot of overhead, CU faculty identified team-related distractions that were burdensome to teams of 5 or even smaller. As group orientation is one of the original principles of TRAILS, CU hesitated with its transition from group to individual projects initially but in the end concluded that the products as well as the learning facilitated by individual work significantly outweighed the anticipated benefits of group orientation in their particular course.

While CU students did not work in a traditional group-oriented way, this did not mean that students were learning completely independently. CU instructors noticed significant group learning emerging from mutual inspiration in various social settings. The middle school classrooms served as a physical social setting. Students would not only test their own gamelets but would also watch other students testing theirs. CU faculty report that students were highly motivated by witnessing firsthand the success or failure of their designs. The Gorp system itself served as a virtual group learning tool. Due to the ease of downloading other students' games and playing them, most students played each others' games without being required to do so. In doing that, they naturally absorbed new ideas from each other.

It certainly would be an overgeneralization to claim that group orientation is problematic in a learning technology design course. Over the years some great CU projects were designed by teams—for example, the Agent Hunt game created by a multidisciplinary group of computer science, fine arts, and English majors. However, group orientation must be handled carefully. In CU's final assessment, PI Alex Repenning writes, "The classical approach where students are

bunched up into a group because 'this is how the real world works' is likely to [result in lessons about] either about working in a group or about a subject area but not both."

Design students need to learn to think about projects as open-ended, complex, iterative challenges rather than closed-ended ones admitting of single solutions

At the end of Y4, we completed a preliminary analysis of our TRAILS survey data. We found that in some cases, such as responses to the paired value statements and the conceptual diagramming at the end of the survey, we did not see noticeable differences between the novice responses of the TRAILS students and expert responses. One possible explanations for these similarities is simply that the item was obvious. However, our sense from working with many TRAILS students over the years is that the questions we posed were challenging and revealing. So, we believe that by the time students participated in the TRAILS survey at the end of the quarter or semester, the course had effectively trained them to expert-level thinking for that particular aspect of the design work.

On the other hand, in other items such as the practice scenarios, there was a striking pattern of differences between novice and expert responses. The table below show representative responses for two practice items. In the first practice item we saw novices offer various ways to solve a design problem. By contrast, the experts all seemed to acknowledge that there was no perfect solution; their answers implied that in practice design required "satisficing" (to use Herb Simon's expression). In a second practice item, novice responses revealed the students' belief that design problems are self-contained. In other words, they believed that design problems could be solved solely by examining the immediate context of the learning situation.. But the expert responses emphasized the need to always go beyond the immediate context and apply a scholarly approach to incorporate findings from related work.

	Sample Novice Response	Sample Expert Response
Solving vs. Satisficing	N1: "Suggest thinking about time constraints, level of the students, costs and the overall learning good desired or how much the level of student education must increase." N2: "Have two – prototypes; test within group; (If needed) test with other colleagues; (If needed) test with students."	E1: "…I'd ask questions like: What were the features/variables of such studies? Under different conditions (different teaching styles, different visualization tools, different types of data sets or contexts, etc.), might [we see] different results?…"
Self-containment vs. Scholarship	N3: "Go to schools and observe the classrooms. Take a survey regarding teachers needs/desires." N4: "Conduct a survey to get ideas what kind of technology is	E2: "…Principals and district administrators could also provide good feedback (especially since they control budgets and curricula). Check the literature or

	available and what level of technology knowledge do teachers have."	other reports for reviews on available applications, their strengths & weaknesses. Study the existing curricula and standards. Whatever we develop has to align with them."

From these findings, we theorize that a key issue in teaching a course on learning technology design is overcoming students' school-success strategies. Examples of survival strategies include getting the "right answer" and leveraging immediately available information sources without questioning the validity and completeness of the data. Research shows that students in K-12 adopt sophisticated strategies for success that can be at odds with real learning gains or the development of practices that would serve them well as professionals (e.g. see Denise Pope's work on "Doing School"). For courses like TRAILS, we believe it is important to highlight how design is about exploring tradeoffs and drawing from many sources of related work to arrive at promising solutions.

Training & Development

What research and teaching skills, and experience has the project helped provide to those who worked on the project?

Vicki Bennett, a new doctoral student for TRAILS from the Department of Communication at CU, gained research experience in interviewing.

Outreach Activities

What outreach activities have you undertaken to increase public understanding of, and participation in, science and technology?

In the fall of 2005 Chris DiGiano traveled to a meeting run by EPIC (Engaging People in Cyberinfrastructure), a $3M, 15 month project aiming to build human capacity through cyberinfrastructure. EPIC has subgroups devoted to topics such as Asynchronous Training, Computational Science Curriculum, Visualization in Education, and Women and Girls and Cyberinfrastructure, and has an excellent project reporting infrastructure. Like TRAILS people, EPIC participants are intensively concerned about how to get computational science into the high school and higher-ed curricula. Software environments including ActiveWorlds , Torque 3D Game Environment, and Croquet were demonstrated. The meeting was a good opportunity to learn about how the notion of "cyberinfrastructure" evolved in NSF and meet people who are thinking about educational applications.

Members of the TRAILS team presented at the following conferences.

- In March 2006 it presented a poster at SIGCSE 2006 titled "So you want your students to design educational applications? Learning technology design as a context for computer science project work."

- Chris Hoadley's paper, titled "Just-So" Knowledge: The Role of Design Knowledge in Fostering Learning and Empowerment", was accepted by the 2nd International Conference on Technology, Knowledge and Society, and presented in December 2005, in Hyderabad, India.

In June 2006 Stanford presented at ICLS (International Conference of the Learning Sciences) at Indiana University at Bloomington on the topic of "Collaborating to Learn, Learning to Collaborate: Finding the Balance in a Cross-Disciplinary Design Course." That same month, CU ran a workshop entitled "Gamelet Design for Education" at The Games, Learning and Society Conference 2006 conference in Madison, Wisconsin.

Michael Chorost, Alex Repenning, Clayton Lewis, and Chris DiGiano attended a conference run by the Coleman Institute for Cognitive Disorders in Boulder, Colorado. The Coleman Institute supports research into assistive technologies for people with cognitive disorders such as Down's Syndrome and Parkinson's. The conference offered significant alignment to TRAILS's goals in that TRAILS is about teaching people how to design for learning. Chorost's talk was titled "Beyond Cochlear Implants: Implications for Cognitive Technologies," and he talked about the possible applications of neurotechnology for brain implants. Clayton Lewis ran a panel on commercializing assistive devices for the cognitively disabled.

Brenda Bannan-Ritland, a George Mason University professor visiting Stanford, saw a demonstration of TRAILS resources and wrote us an email noting that the content on the TRAILS wiki would be of use in her courses. She had special praise for Gorp and the compiled list of LTD courses nationwide. She wrote, "I would be very interested in how we could involve some of our student-generated projects from George Mason University in this effort...we have been developing technology-based prototype products for clients for the last five years and have worked with the Virginia Department of Education, Office of Special Education Programs and currently the Mine Safety and Health Administration, among others." Gucci Estrella wrote Dr. Bannan-Ritland back with information about TRAILS and an invitation to participate at more length.

Publications & Products

New journal publications resulting from this work

— none for Y4 of TRAILS —

New books or other nonperiodical, one-time publications resulting from this work

DiGiano, C. (2006). So you want your students to design educational applications? Learning technology design as a context for computer science project work. Poster presented at ACM SIG Computer Science Education.

DiGiano, C., Kireyev, K., & Repenning, A. (2006). Evolving tools organically with computational wikis. Paper presented at the Computer Supported Cooperative Work (CSCW 2006).

Mercier, E., Goldman, S. & Booker, A. (2006) Collaborating to Learn, Learning to Collaborate: Finding the balance in a cross-disciplinary design course. *The Proceedings of the Seventh International Conference of the Learning Sciences (ICLS)* (Vol 1, 467-473). Mahwah, NJ: Erlbaum.

Repenning, A. (2006). Excuse me, I need better AI! Employing Collaborative Diffusion to make Game AI Child's Play. In Proceedings of the ACM SIGGRAPH Video Game Symposium, (Boston, MA, 2006), ACM Press.

Repenning, A. (2006). Collaborative Diffusion: Programming Antiobjects. in OOPSLA 2006, ACM SIGPLAN International Conference on Object-Oriented Programming Systems, Languages, and Applications, (Portland, Oregon, 2006), ACM Press.

Repenning, A. and Ioannidou, A. (2006). AgentCubes: Raising the Ceiling of End-User Development in Education through Incremental 3D. in IEEE Symposium on Visual Languages and Human-Centric Computing 2006, (Brighton, United Kingdom, 2006), IEEE Press.

Other specific new products (databases, physical collections, educational aids, software, instruments, or the like) resulting from this work

- TRAILS Gorp (Gallery, Organizer, and Repository of Projects): http://trails-project.org/webapps/gorp/

- Gamelets for Education Web site featuring the curriculum, homework, projects, references, schedules, and a discussion forum: http://www.cs.colorado.edu/~ralex/courses/gamelet2006/

Contributions

TRAILS is uncovering important findings for the fields of computer science and education. We have also identified key services and resources needed to centrally and flexibly support multiple implementations of our course modules. We have identified challenges in getting students from different disciplines to work together effectively. We believe these findings are drawing out common issues in motivating and supporting teams of designers.

Ultimately, we see our TRAILS research as leading to new ways to train the next generation of learning technology designers and to create exemplary digital content in the process. In the end, we anticipate that our work will affect K-12 education by providing better technology and teachers who are better able to take advantage of it.

1. The principal discipline(s) of the project

- In computer science, TRAILS is contributing to the field's understanding of the value of game-oriented courses. Such courses could bring back some of the energy and increase

the enrollment in computer science. Nationwide, computer science programs have experienced an enrollment drop between 20% and 50%. This decline could be a significant problem for IT training, which to a large degree depends on computer science. Game-oriented courses have the potential to serve as application courses that not only motivate students but at the same time provide enormous learning potential because of their integrative nature.

- In computer science and in education, TRAILS is contributing models for how students in project courses can receive authentic feedback on their ideas. At least three different models have emerged, which we plan to compare and contrast in a journal article.

- In computer science and in education, TRAILS is contributing models for interdisciplinary collaboration between university students.

2. Other disciplines of science or engineering

- We anticipate that lessons learned in computer science and education will transfer readily to the design of courses in other disciplines, such as a mechanical engineering project course.

3. The development of human resources

- TRAILS is fundamentally about the development of human resources for the design of high-quality learning technologies. Now in Y4 of the project, we have a growing collection of stories of alumni going on to do great things. At CU, students have credited the TRAILS course with helping them find better jobs because of their exposure to state-of-the-art technologies, including, for instance, artificial intelligence in game programming. Other students have become teachers and used some of the TRAILS tools and teaching materials. At Stanford, alumni have taken jobs in the technology sector, where they report they are applying their learner-centered design techniques.

4. The physical, institutional, or information resources that form the infrastructure for research and education

- A central goal of the end of the TRAILS project is to ensure that design resources for instructors and students are appropriately packaged and disseminated so as to have a lasting impact on higher education. We see the book we are writing as the main vehicle for sharing our experiences.

Participants

What people have worked on your project?

SRI International
Mark Chung, research staff
Chris DiGiano, PI
Gucci Estrella, research staff (new for Y4)
Judi Fusco, community development advisor (new for Y4)
Rena Fuji, research staff (new for Y4)
Jeff Huang, research staff
Jennifer Knudsen, curriculum advisor
Charles Patton, technical advisor
Michael Griffin, research staff
Mark Schlager, curriculum advisor
Jeremy Roschelle, advisor
Anders Rosenquist, research staff (new for Y4)
Wenming Ye, research staff

Math Forum
Suzanne Alejandre
Vanessa Gorman
Gene Klotz
Cynthia Lanius
Kristina Lasher
Whitney Nekoba
Melissa Running

University of Colorado, Boulder
Kavita Agrawal, undergraduate student working on thesis
Vicki Bennett, GRA (new for Y4)
Jacob Dickerson, GRA
Michele Jackson, faculty
Clayton Lewis, faculty
Alexander Repenning, co-PI
Chris Schenk, undergraduate student
Jennifer Turney, GRA
Stacy Wieland

Stanford University
Angela Booker, GRA
Shelley Goldman, co-PI
Roy Pea, faculty advisor
Emma Mercier, GRA

Drexel University
Frank J. Lee, faculty seed grant recipient
Yelena Kushleyeva, GRA

Pennsylvania State University
Christopher Hoadley, faculty seed grant recipient
Charles Cox, GRA in Instructional Systems (Education)
Paula Bach, GRA in Information Sciences and Technology

Swarthmore College
Ann Renninger, faculty
Allen Frost

Independent Consultants
Michael Chorost, writer and partner liason
Jody Underwood, curriculum advisor

Other collaborators or contacts
U.S. Universities & Colleges
Mark Guzdial, Georgia Institute of Technology
Jochen F. Rick, Georgia Institute of Technology
Mindy Hart, Comp. Sci., Purdue University
Edward J. Kobrinski, St. Mary's College of Maryland
Jeff Kushner, James Madison University
Andrea Spurgeon, Carrollton School of the Sacred Heart
Lori Scarlatos, Dept. of Comp. & Info. Sci., Brooklyn College, CUNY
David Redmiles, School of Info. & Comp. Sci., UC, Irvine
Joel Duffin, Utah State National Library of Virtual Manipulatives
Larry Leifer, Director, Stanford Center for Design Research
Sue Giller, PhD student at the University of Teesside with Prof. Barker
Carl Wieman, Dept. of Physics, University of Colorado at Boulder
Valerie K. Otero, School of Ed., University of Colorado at Boulder
Tammy Sumner, Dept. of Comp. Sci., University of Colorado at Boulder

International Affiliations
Steve Rudolph, Jiva Institute, India
Arkajit Mandal, Jiva Institute, India
Cesar Nunes, The School of the Future, Univ. of Sao Paulo, Brazil
Manolis Koutlis, Faculty, Univ. of Patras, Greece, and Talent S.A.
Chronis Kynigos, Faculty, Univ. of Patras, Greece, and Talent S.A.
Lisiane Oliveira, Universidade Federal de Espirito Santo
Johan Gademan, ThiemeMeulenhoff Publishing, The Netherlands

Centers & Organizations
David Boyce, Almanac News Adam DiGiacomo, Team Labs Corporation Michael Gross, Schoolteacher, New York
School Marie Bienkowski, SRI International Ted Kahn, Design Worlds Consulting
Robert M. Panoff, The Shodor Education Foundation, Inc. Curtis Sears, Jr., NSF Division of
Undergraduate Education Kenneth Whang, NSF CISE/EIA John Cherniavsky, NSF EHR SBIR Mark Saul, NSF EHR Elementary,
Secondary, & Informal Education Gerald Hanley, MERLOT Thor Anderson, Ph.D., Manager, Program
Development Online and Academic Services, Collegis, Inc.

Acknowledgments

This material is based on work supported by the National Science Foundation under Grant No. 0205625. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.