TRAILS Final Report[1]
August 2002 – August 2007

"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

Over the last five years, the TRAILS project partners have worked 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 focused on engaging teams of university students in the creation of learning technology through project-based design courses. Through these courses, TRAILS hoped to have three major effects (as illustrated in Figure 1): 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.

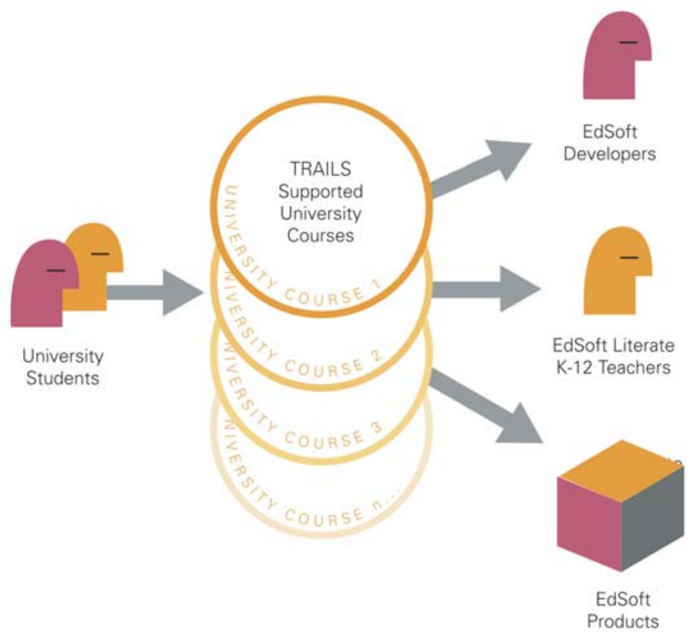

Figure 1: The original TRAILS plan for impacting developers, teachers, and products.

[1] This material is based upon 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.

The first goal of preparing learning technology designers was a great success. In total, TRAILS-affiliated courses reached over 300 students, as detailed in Table 1. Rather than try and promote a rigid structure across participating courses, we deliberately seeded a range of approaches to learning technology design (LTD) instruction. 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. One sign of success is that TRAILS-affiliated courses are being adopted at foreign institutions. Alex Repenning of the University of Colorado at Boulder (CU) started a new education games course at the University of Lugano while he was there on leave.

Table 1. Participation in TRAILS-affiliated courses.

	CU Boulder	***Penn State***	***Stanford***	***Drexel Univ.***	***Total***
Most recent course title	Gamelet Design for Education	Designing Educational Technologies	Collaborative Design and Research of Technology-Integrated Curricula	Educational Gaming	
M/F ratio of most recent course	10/4	70/10	8/6	N/A	88/20
Grad/undergrad ratio of most recent course	1/13	0/80	11/3	N/A	12/96
Total students since August 2002	78	150	52	21	301

Midway through the project we transformed our second goal of preparing teachers to use learning tools, to preparing them to be the best mentors for student projects. We learned how to train practicing teachers to give constructive feedback on learning technology projects and guide students to think creatively, but also realistically, about classroom learning environments and beyond.

As for our goal of generating new tools for K-12 education, many of the TRAILS projects did end up being used by students. For example, a Stanford project, Searchy, was an exhibit at the San Jose Tech Museum. Other projects ended up getting published on the MathTools Web site[2] run by the Math Forum at Drexel University. We had hoped that there might be a more automatic way for student projects to be published, but in the end it was clear that each course was creating different types of products, some more finished than others. For this reason, it made sense to promote individual projects on a case-by-case basis.

In the remainder of this report we review highlights of the last five years of activity and also review key findings from the project. An appendix offers details on the main deliverable for our project, a new book to be published by Taylor and Francis.

[2] http://mathforum.org/mathtools/. Last accessed October 26, 2007.

Activity Highlights

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

Year 1: September 2002 – August 2003

In Year 1, the project spent its first six months establishing project infrastructure and identifying key research issues. In the winter, this activity quickly shifted towards TRAILS course design as we seized on opportunities at both Stanford and CU to test the TRAILS university curriculum on experimental courses during the spring. This was six months ahead of our original plan, but we decided that the early experiences could help catalyze our curriculum design activities and give us more chances to iterate on our approach. The early experimental courses also helped jump start work on centralized tools and guidance for TRAIL students and instructors.

We established a prototype on-line "Design Space" where students and instructors can share intermediate design artifacts, where outside experts can review student work and offer commentary, and where final products can be archived. We chose an existing, full-featured and flexible content management system called "Tiki" as a starting point for the Design Space. Our goal was to quickly bootstrap our design support system without committing ourselves to developing a customized homegrown solution.

We also experimented with supporting students through "Trail Guides," experts who made themselves available through email, instant messaging, and, in some cases, personal visits to the TRAILS classroom. For each course in the spring, we provided a technical Guide who could advise students on issues concerning programming languages, configuration management, and general software architecture. We also provided a pedagogical Guide who could help students with their curricular focus, teaching strategy, and the organization of student materials and teacher guides.

Year 2: September 2003 – August 2004

The highlight of Year 2 was the offering of 2 updated TRAILS-affiliated courses at Stanford University and CU. These courses benefited from the experience of running the experimental TRAILS-affiliated courses earlier in Year 1 at the same two universities. Both sites used a more structured syllabus, more education-oriented readings, and more built-in opportunities for testing in K-12 classrooms.

Experience from Year 1 also informed new strategies for designing online tools to scaffold student learning and provide guidance for students and instructors. Rather than continue using the off-the-shelf Tiki system, the TRAILS team developed a custom Web application called the "Gallery of Reusable Projects" (the acronym, GORP, is a word play on trail food, http://trails-project.org/webapps/gorp). GORP is an online tool enabling students and instructors to collect, categorize, describe, and evaluate educational tools. For precision's sake, we called these tools interactive "curriculets" rather than "applets" to underscore the fact that a complete educational application needs to be packaged along with instructions, teacher notes, and linkages to educational standards in order to realize its full value. GORP aimed to scaffold students' learning by leading them through a step-by-step process where they consider the same questions a professional instructional designer would ask while reviewing an interactive tool.

The project also conducted a competition to choose two additional university course sites to join the TRAILS network. Frank Lee, an assistant professor from Drexel University, and Chris Hoadley, an assistant professor from Pennsylvania State University were selected to offer TRAILS-affiliated courses the following year.

Year 3: September 2004 – August 2005

In Year 3, we expanded TRAILS to a total of four pilot courses across the country, initiated an evaluation plan, and began publishing our lessons learned. Two new courses came online: one at Drexel University and the other at Penn State University. Drexel pioneered a new feedback process that enabled master teachers to comment on evolving projects. Penn State experimented with a new multidisciplinary model, combining a graduate seminar in Instructional Systems Design and an undergraduate course on Human-Computer Interaction.

Our new comprehensive project evaluation plan featured an innovative student survey instrument for assessing the impact of a project-based design course on students' notion of content knowledge, processes, and design values. Additional evaluation instruments included debriefings with instructional staff and selected students after each TRAILS course; a protocol for reviewing the structure of each course through its syllabi, activities, and readings; and analysis of course artifacts, such as projects cataloged in our Gorp Web application (http://trails-project.org/webapps/gorp/).

Meanwhile, our veteran partners at Stanford University and CU implemented major improvements to their previous TRAILS courses. Stanford adjusted how students interact with educator-partners and added group participation to the grading rubric. CU worked to manage student expectations by renaming its course "Gamelet Design."

Year 4: September 2005 – August 2006

The dominant theme of Year 4 was shifting our efforts towards dissemination and ensuring the project's legacy. We began organizing a book targeted toward university instructors and their students, which has since been titled *Educating Learning Technology Designers: Guiding and Inspiring Creators of Innovative Educational Tools* (ELTD).

To complement the ELTD book, we launched another major Year 4 initiative: designing a new interactive public Web site, "Learning about Learning Technology Design" (L^2TD, see Figure 2). On this new site, we consolidated and extended our online resources, and also enabled the community to further refine the content through the site's Wiki infrastructure. Our hope is that this site will live beyond the formal end of the TRAILS project, so all content was edited to remove any assumptions about TRAILS. For example, we did not want to call our courses "TRAILS-affiliated courses," but instead describe them more generically as possible course models.

Three TRAILS-affiliated courses were taught in the fall and winter, reaching a total of 30 university students:

1. “Designing Educational Technologies” at Penn State University
2. “Collaborative Design and Research of Technology-Integrated Curricula” at Stanford University
3. “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 allowed our dissemination and outreach activities to continue until 31 August, 2007.

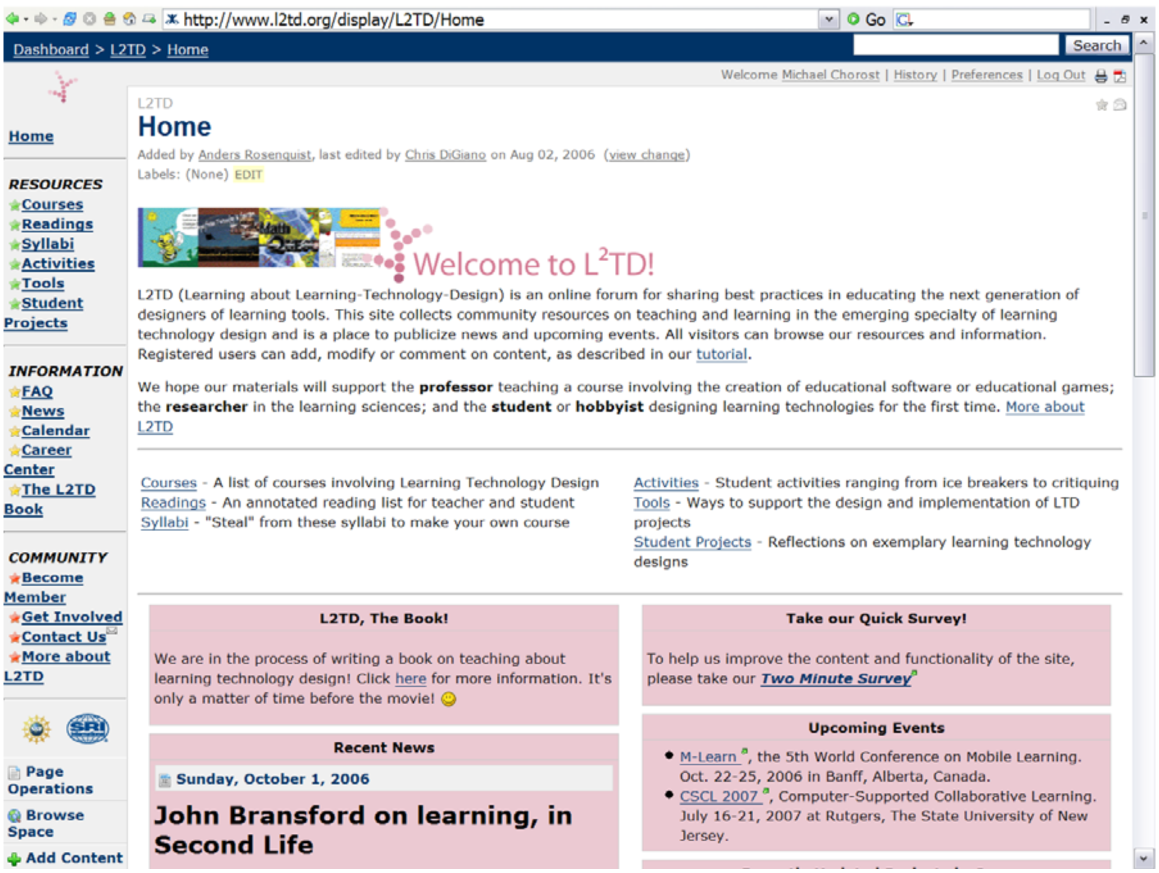

Figure 2. The public Web site for Educating Learning Technology Designers. The site is intended to live beyond the duration of this project.

Year 5: September 2006 – August 2007

This last “extension” year of the project was focused on our forthcoming book, *Educating Learning Technology Designers*, to be published by Taylor and Francis. During this year we finalized the structure of the book and managed the writing and editing of its 14 chapters. We were particularly pleased to attract so many outside authors—contributors who were not part of the original TRAILS project: Deborah Tatar from Virginia Tech, Chris Quintana from Univ. of Michigan, Jennifer Robinson and friends at Univ. of Indiana, and Brett Shelton from Utah State.

Chris Hoadley and colleagues from Penn State Univ. (who were recipients of seed grants from this project) also provided two chapters.

Book writing was not the only dissemination activity in Year 5. We also wrote a white paper titled "Choosing Outreach Strategies to Increase Interest in IT Careers," which we distributed at SIGCSE 2007. Below is an excerpt from the introduction:

> Even as American youth are wholeheartedly embracing information technology (IT) for communication and entertainment, many signs indicate that they are losing interest in understanding and advancing the computer technology that drives it. The industries that rely on an IT-savvy workforce can and must play an active role in reversing this trend. This whitepaper analyzes model outreach programs and offers a framework for helping a company identify the most appropriate strategies for helping reinvigorate interest in IT.

Despite the fact that TRAILS-affiliated institutions were no longer required to offer learning technology design courses during our extension year, there were two repeated course offerings:

1. "Designing Educational Technologies" at Penn State University, 80 students (in two sections).
2. "Collaborative Design and Research of Technology-Integrated Curricula" at Stanford University, 14 students.

Shelley Goldman and her graduate students at Stanford continued to use their course as a laboratory for understanding collaboration in groups and the importance of working with K-12 teachers. They conducted observations of the class, collected journals and interviewed students and clients.

Meanwhile at CU, Michele Jackson in the Communication Department collected data regarding learning technology and game design/development courses at universities affiliated with the America Association of Universities (AAU) (http://www.aau.edu/aau/members.html). This included a review of existing literature on game studies in higher education. Results from her analysis are being used to inform the introductory chapter to *Educating Learning Technology Designers.*

At the Math Forum, the Teacher Scaffolding Module (TSM) was ported from a project within the Gorp system to its own dedicated Web site. The Math Forum found the original TSM so useful for helping teachers provide effective comments and suggestions on LTD projects, that they wanted to host it on the Math Forum servers where they could continue to refine and customize it. A new graduate student to TRAILS, Quincy Brown, doctoral student in computer science at Drexel University, was integrally involved.

Findings Highlights

What are your major findings from the activities identified above?

Design feedback from learners and educators is critical for TRAILS students.
All four of the TRAILS courses report that design feedback from either target learners or experienced educators is critical for university students who are learning technology design. The variety of feedback strategies used by each course suggests that there may not be one ideal feedback mechanism; what matters is that students have the opportunity to get reactions to their ideas. The importance of educational feedback is also supported by preliminary findings from a study at Drexel of employers' perceptions. Survey responses indicate the need for "testing, testing, testing" and "pedagogical direction."

At Drexel, student design documents were critiqued remotely by a team of educators who added textual annotations to elements in each project's Gorp entry. Drexel found that close university/K-12 collaboration through a feedback process can be enormously fruitful for both the students and the course instructors. However, the researchers noted that typical university students have little to no experience with structuring their work on the basis of feedback from external collaborators, be they teachers or professionals from some other field. For this reason, courses need a well-planned system for encouraging and promoting responsiveness to teachers' feedback. One such approach adopted by Drexel was to require students to respond to teacher feedback with a "cover letter" that explained how they addressed the teachers' concerns. Such mechanisms can increase the likelihood that students worked with and learned from teacher feedback.

At Stanford, each team was required to identify and meet with a practicing "partner educator" who acted as a client. Each team was also encouraged to consult with content experts for the material the team was trying to teach. Students seemed to take advantage of content experts, and the final projects showed evidence of their discussions. Field tests and observations in the classes of partner educators continued to be "eye-opening," benchmark events for the students. Students all indicated that it is well worth the extra effort. Stanford also found indications that increased requirements for interactions with partner educators enhanced not only the quality of resulting projects but also the group process.

Both Penn State and CU adopted a "play testing" strategy, which is now commonplace in computer game and toy design. CU arranged for its TRAILS students to share their prototypes with children in a computer club at a nearby middle school. The TRAILS instructor, Alex Repenning, reported a similar "eye-opening" effect as at Stanford. TRAILS students at Penn State traveled to Baltimore to drop in on a weekend workshop with middle school children and receive feedback on their designs. Prior to this face-to-face experience, children in this workshop gave advice and feedback to the TRAILS students through an online videoconference. Penn State's experiences suggest that involving children in the university students' educational technology design training is a feasible and motivating way to improve undergraduate and graduate education.

Regardless of the feedback mechanism, TRAILS students heard the message that feedback is important, and the earlier the better. Our cross-institutional survey of TRAILS students (before and after their participation in the course) revealed a significant increase in the value that students placed on earlier feedback on their designs.

Game orientation is a powerful motivator, as long as it is well bounded.
Both of the TRAILS courses that had a game orientation in their learning technology projects reported many advantages to the focus on gaming. Drexel found that although students may have different levels of interest in learning about educational content, the context of game design helped students learn about and get practice in educational content. CU found that the notion of "gamelets" helped focus the design processes that they promoted in their class. When scaffolded with the right process and tools, CU students could engage in learner-centered, iterative development approaches resulting in a good balance between learning and engagement goals. A study by CU undergraduate Kavita Agrawal found that a game design orientation has the potential to get more women involved in information technology. However, game design needs to be conceptualized as a social design process including non-programming activities, such as the creation, selection, and sharing of art and sound.

Both TRAILS courses found it important to bound the game designs that students took on. Drexel accomplished this by asking students to focus on design *documents*, not prototypes. CU learned from previous instantiations of its course to emphasize small games at the level of Pac-Man. CU found that its gamelet design process could even be compressed to a single-day workshop to teach people with no programming background how to design and implement simple games.

Multidisciplinary teamwork in higher education is valuable, but difficult to achieve.
Most of us in the TRAILS project continue to believe that multidisciplinary teamwork is one of the most effective means of achieving high-quality designs for learning technologies. This belief was supported by the preliminary results from a survey by Drexel of employer perceptions, which found a common need for collaboration among educators, students, and developers. However, our work has also highlighted the complexities of multidisciplinary teamwork in higher education. Not only do TRAILS instructors and staff struggle to find ways to best organize and incentivize student teams, but students themselves are surprised by the effort involved in coordinating their work. One source of evidence is our cross-institutional survey of TRAILS students, which revealed that students initially underestimate the frequency of project team meetings that are needed for joint decision-making. Penn State data showed that students benefited from interacting with others from different disciplines and enjoyed working on educational technology projects. However, students highlighted difficulties with coordinating graduate and undergraduate students' work schedules.

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.

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.

We compared expert and novice learning technology designers in a survey and performance assessment administered during Year 4 of TRAILS (details in our Y4 report[3]). We found that compared to expert respondents, TRAILS students thought design problems were more solvable. By contrast, the experts all seemed to acknowledge that there was no perfect solution; their answers implied that in practice design required "satisficing." In another survey item, TRAILS student 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.

This study has led us to theorize that a key issue in teaching a course on learning technology design is overcoming students' school success/survival 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.

[3] All of the project reports can be found at http://www.trails-project.org/publications.html.

Courses in learning technology design are found in a majority of research universities. In Michele Jackson's analysis of course offerings and curricula at major research universities (she reviewed Web sites of Association of American University, AAU, members), she found that 56% (35 of 62) of them offered something relating to learning technology design. Most often, each of the 35 institutions that were a clear "yes" meant that they had a presence in a course. But, occasionally, the presence went beyond courses to some other institutional presence (such as being part of academic support or a research lab (e.g. UC Berkeley).

Game design and development courses present new opportunities to design for learning. Reviewing course catalogs, program descriptions, and websites of the AAU institutions reveals that, for approximately 1/3 of them, games and new learning technologies have little to no presence at all. A small set of programs possess an established, vibrant community of game design and game studies. The key for these institutions is that games are seen as a legitimate, robust area of teaching, learning, and research. Of critical importance to the TRAILS project is that the traditional perspective that sees games as an engaging way to package or deliver learning content is superceded by a view that, by making games part of the entire enterprise, content (such as learning) is brought back to the central focus. For example, Michigan State University offers an interdisciplinary program fully in the mold of a traditional academic program, with approximately one dozen faculty working in the area of educational games[4]. At the University of Southern California, game design and game studies is a focus that weaves throughout a range of disciplines including computer science and design, but is also distinguished by a high involvement of the humanities and education. At these institutions, because games and (more generally) the nature of design in online context is so thoroughly integrated into the academic environment, the focus of teaching and research instead returns to enduring questions of how to design, use, and analyze technologies for enduring issues such as communication, collaboration, teaching, and learning.

LTD students value teacher feedback, but act on it only when it is presented properly. The Math Forum undertook two types of studies: one focused on characterizing student developers, their strengths, needs, experiences, and interests for understanding the learning of mathematics, and the other focused on teachers' scaffolding acts and the undergraduate students abilities to work with and make use of this information. Findings from the analyses provide more detailed information about a main principle of human-centered design: that collaboration with professionals (e.g., expert teachers) provide support for designing use-informed products.

More specifically, findings from this work suggest that:

- Students realized that teachers were an important audience for their designs.
- Teachers could not rely on their expertise as a reason for designs to be changed unless expression of expertise was coupled with a question. Student groups appear to need to feel that their ideas are respected and that they are in a conversation in order for change to occur.

[4] Games for Entertainment and Learning, http://www.gel.msu.edu/

- Teachers sometimes raised questions intending to support thinking and instead reinforced student groups to not develop more educationally relevant aspects of their design.
- Student groups who primarily received compliments were more likely to not include scaffolding-feedback in their designs, explaining that it was not necessary. Student groups who received criticism were more likely to include scaffolding-feedback in their game designs.
- Differences of interest for software, mathematics, and group work may have contributed to whether student group designs developed over time.

Central supports for a course network require market analysis, packaging, and advertising.

In growing the network of TRAILS-affiliated courses, SRI encountered new challenges in providing useful central supports. As the network grew, SRI found itself trying to support a greater range of teaching goals, more diversity in knowledge of learning technology design, and an increasing variety of teaching styles. Our semiannual face-to-face "Partners Meetings" proved to be one of our most effective means of building consensus around principles for teaching learning-technology design and sharing informal course design knowledge. Less effective were our electronic resources, such as our reading list, which we had hoped would provide a common foundation of literature for our courses. When we reviewed the readings that were actually listed in the syllabi of TRAILS-affiliated courses, we found that a disappointing 20% of the readings came from our centralized list. Transfer of activities captured in our Web site from one course to another was also been limited.

Clearly, even among formal partners, the effective sharing and transfer of course resources must be managed like a commercial enterprise: significant time and energy must be devoted to market analysis, packaging, and advertising. SRI had to be more careful to understand the needs of instructors, organize resources in a portable form that allows for local adaptation, and then advertise these resources across our network.

When it comes to technical resources such as Gorp, SRI found that a course instructor is less interested in tools to support design reuse across institutions than in tools that help students organize projects in terms familiar to the course. SRI also found that project content stored under individual student accounts is at risk of being lost, so there is a need for ways to archive projects effectively. These realizations caused SRI to iterate on the design of the TRAILS Gorp system, adding support for course-specific categories of information for student projects and ways to upload project content for the long term onto SRI servers. Consequently, SRI changed the meaning of the Gorp acronym from "Gallery of Reusable Projects" to "Gallery, Organizer, and Repository of Projects."

Training & Development

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

In addition to the 300+ graduate and undergraduate students who participated in our learning technology design courses, we also gave research and teaching experience to eight graduate research assistants from four different institutions. These RA's played a variety of roles on the project, from helping us design the TRAILS-affiliated courses, to teaching them, to collecting data from courses, to writing up results. In several cases, the TRAILS experience was central to the student's Ph.D. dissertation. Furthermore, we expect the training and development impact of TRAILS to continue for many years with courses in LDT continuing to be taught at all four partner institutions and derivative courses appearing at other institutions as well.

Outreach Activities

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

Below we highlight some of our most important outreach activities over the last five years:

- Throughout the project we have worked hard to involve educators in K-12 public schools and in museums as mentors or clients to university student project teams. Our interactions with educators have ranged from face-to-face meetings to on-line critiques. Indeed, part of our research has been to identify ways for these teachers to have a voice in learning technology design and, in the case of the Math Forum's TRAILS work, how to train the educators themselves to be the most effective mentors possible.
- Throughout the project we have also reached out to young learners in these public school and museum settings in an effort to gain their input on candidate learning technology designs. This often involved bringing prototype tools to a classroom or after-school setting and asking learners to give us their honest feedback.
- 2005 - CU's gamelet concept was used very successfully at the Women in Engineering Career Day at University of Colorado. Prospective students with their parents created simple games using AgentSheets.
- 2005 - Drexel represented TRAILS on a panel at the Consortium for Computing Sciences in Colleges' 2005 conference (CCSCNE 2005, http://www.ccscne.org), held at Providence College, RI. Their panel was titled "Innovation in undergraduate computer science education."
- 2005 - CU's Michele Jackson gave a panel presentation at the International Communication Association (http://www.icahdq.org). Jackson participated in the discussion titled "Games and Human Interaction: Curriculum and Research."
- 2005 - Penn State helped expose middle school children to participatory design by having its TRAILS' university students participate in the University of Baltimore's KidsTeam initiative.

- 2005 - The team hosted a symposium at ED-MEDIA 2005 in Montreal titled "Challenges in Developing Authentic, Multi-University, Cross-Disciplinary, Design-Based Courses."
- 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
- 2006 - CU ran a workshop entitled "Gamelet Design for Education" at The Games, Learning and Society Conference 2006 conference in Madison, Wisconsin.
- 2007 - As described in more detail above, the SRI TRAILS team produced a whitepaper designed to offer guidance to industry on how to collaborate with academia to broaden participation in computing.
- Alex Repenning distilled his semester-long TRAILS course at CU down to a 5-week mini-course for middle schoolers. This workshop has now been offered for several years as part of the University of Colorado Science Discovery summer program. The course has become so popular that in the summer of 2007 it had to be offered three times.

Publications & Products

Journal Publications

Ioannidou, A., A. Repenning, et al. (2003). "Making Constructionism Work in the Classroom." <u>International Journal of Computers for Mathematical Learning</u> **8**(1): 63-108.

Booker, A., Mercier, E. & Goldman, S., (2002). "We Know the Drill: The need to unlearn bad habits, become open, and attend in novel ways to new collaborations." Paper submitted to the International Conference of the Learning Sciences.

Repenning, A. and A. Ioannidou (2004). "Agent-based end-user development." <u>Communications of the ACM</u> **47**(9): 43-46.

Repenning, A. (2005). "Inflatable Icons: Diffusion-based Interactive Extrusion of 2D Images into 3D Models." <u>The Journal of Graphical Tools</u> **10**(1): 1-15.

Renninger, K. A. Lee, F. Alejandre, S. Frost, A., (in preparation). "Learning' in a course on educational gaming: What did they do? What do they think they learned?"

Renninger, K. A. Lee, F. Alejandre, S. Frost, A., (in preparation) "Providing student developers with feedback: How?"

Mercier, E., (in preparation). "What makes one group succeed where another fails? Evidence from two case studies."

Book(s) or other one-time publications(s)

Renninger, K. Ann, Shumar, W., Digiano, C., and Alejandre, S., (2004). "Collaboration as a Foundation for the Design and Usage of Technology Rich Problems." NCTM Presentation.

Renninger, K., DiGiano, C, Shumar, W., & Alejandre, S., (2004). "Collaboration as a Foundation for the Design and Usage of Technology Rich Problems." NCTM Presentation.

Alejandre, S. & Weimar, S., (2004). "Hands-on Introduction to Technology Tools that Help Your Students Learn Math." NCTM Presentation.

Repenning, A. (2003). "The Pragmatic Web: Customizable Web Applications." Paper presented at the CHI 2003 Conference on Human Factors in Computing Systems, Workshop on End-User Development, Fort Lauderdale, Florida.

Repenning, A., & Sullivan, J. (2003). "The Pragmatic Web: Agent-Based Multimodal Web Interaction with no Browser in Sight." Paper presented at the Interact 2003, Switzerland.

DiGiano, C., Griffin, M., Huang, J., & Chung, M., (2003). "Consolidating Ed-Tech Co-Design Best Practices through the TRAILS Project." Poster presented at Innovation and Tech. in Computer Science Education, Thessaloniki, Greece.

Repenning, A. and A. Ioannidou (2006). "What makes End-User Development Tick? 13 design guidelines." In Lieberman, H., F. Paternò, et al., End user development, Dordrecht: Kluwer Academic.

DiGiano, C., Chorost M., Chung M., & Huang J, (2005). "Helping instructors scaffold students' design of educational technology projects." Presented at ED-MEDIA 2005, World Conference on Educational Multimedia, Hypermedia & Telecommunications, Montreal, Canada., (2005).

Hoadley, C. M., & Cox, C. D., (2005). "Educating reflective learner centered designers." Presented at ED-MEDIA 2005, World Conference on Educational Multimedia, Hypermedia & Telecommunications, Montreal, Canada.

Mercier, E., Booker A., & Goldman S., (2005). "Bringing collaboration front and center in a cross-disciplinary design course." Presented at ED-MEDIA 2005, World Conference on Educational Multimedia, Hypermedia & Telecommunications, Montreal, Canada.

Repenning, A., & Clayton, L., (2005). "Playing a game: The ecology of designing, building and testing games as educational activities." Paper to be presented at ED-MEDIA 2005, World Conference on Educational Multimedia, Hypermedia & Telecommunications, Montreal, Canada.

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Contributions

TRAILS uncovered important findings for the fields of computer science and education. We identified key services and resources needed to centrally and flexibly support multiple implementations of our course modules. We identified challenges in getting students from different disciplines to work together effectively. We believe these findings surfaced common issues in motivating and supporting teams of designers. Ultimately, we believe our TRAILS research has lead to new ways to train the next generation of learning technology designers and to create exemplary digital content in the process.

1. The principal discipline(s) of the project

- In computer science and in education, TRAILS contributed models for how students in project courses can receive authentic feedback on their ideas.
- In computer science and in education, TRAILS contributed models for interdisciplinary collaboration between university students.

- In computer science, TRAILS contributed 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.

2. Other disciplines of science or engineering

- We believe our 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 was fundamentally about the development of human resources for the design of high-quality learning technologies. We have many 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 was 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 forthcoming book *Educating Learning Technology Designers* as the main vehicle for sharing our experiences.

Participants

What people have worked on your project?

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Appendix: Details on our forthcoming book

In Spring 2008 Taylor and Francis will publish a unique edited volume, *Educating Learning Technology Designers: Guiding and Inspiring Creators of Innovative Educational Tools*, that we expect will be an invaluable resource for instructors of future courses involving the design of learning technology. The diverse authors bring years of experience designing learning technologies and teaching it to university students. The book has reflective chapters by instructors of LTD and resource chapters with concrete suggestions. Two of the more unusual chapters are a roundtable discussion on multidisciplinary education in higher education, and a collection of featured students projects, which include interviews with the instructors and students. A complete table of contents is below.

Educating Learning Technology Designers
Chris DiGiano, Shelley Goldman, and Michael Chorost, editors

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