

Project Description: Collaborative Research: II: Computing and Other Disciplines: Curricular Guidelines

Vision, Goals, and Objectives:

We envision a nation in which computational thinking (CT) is learned in context in most, if not all, university disciplines. We will prepare curricular guidelines, working with educators in other disciplines, so CT can be learned in those other disciplines. This will help students taking courses in those areas to apply computing concepts in a wide variety of contexts. Thus, almost all those who complete undergraduate studies will be exposed, repeatedly, to CT. Further, those who major in a computing-related field will have key ideas reinforced in other settings, and will be better prepared to apply CT.

Our **project goals** are to:

1. Develop curricular guidelines, linked to suitable curricular materials, connecting computing with other disciplines, that can be deployed nationwide, and ultimately globally. (See Figure 1.)
2. Develop a sustainable infrastructure for the resulting virtual book, *i.e.*, an editorial organization, to prepare, update, extend, and disseminate these curricular guidelines. This will include connecting with ACM, IEEE-CS, and the education committees of various disciplinary societies.

We will address the three goals of the CPATH initiative, as we meet our project goals, as follows:

1. *Contribute to the development of a globally competitive U.S. workforce with CT competencies essential to U.S. leadership in the global innovation enterprise.* Our guidelines will lead to modules and courses incorporating CT that will be studied by nearly all undergraduates, not just those majoring in the computing fields. Since computing concepts will be learned in context, workers will find it easier to apply those concepts; they will already conceptually understand what they find in the workforce, and will have enough experience applying CT in different contexts so that transfer and analogical reasoning will be straightforward. Those majoring in computing will have even more exposure and competency.
2. *Increase the number of students developing CT competencies by infusing CT learning opportunities into undergraduate education in the core computing - computer and information science and engineering - disciplines, and in other fields of study.* We will focus on this goal, especially on “other fields of study”. Since we target “other disciplines” broadly, we reach a very large number of students. Those who study the core computing disciplines also will benefit from having additional exposure to computing concepts within the contexts of their other classes. Note that rather than computer literacy, or familiarity with popular tools and systems (Word, Excel, Access, PowerPoint, Blackboard, WebCT, Sakai, Skype, Google, Google Earth, Photoshop, Flash, Premiere, GarageBand, Matlab, ...), our aim is deep understanding of key concepts that enables application in many contexts.
3. *Demonstrate transformative CT-focused undergraduate education models that are replicable across a variety of institutions.* Since we are preparing a national curriculum, this will serve as a model for nationwide deployment. Since we are working with ACM and IEEE-CS, this should connect with all of their members and student chapters, as well as all who read our publications. By linking with the curricular materials disseminated through NSF’s NSDL, in particular the computing pathway, Ensemble, we will connect with educators through yet another avenue aimed to help their teaching.

Our **project objectives** are to:

1. Extend further the planned editorial structure by adding more people who will provide volunteer assistance in this project, building upon the already established structure shown in Figure 1.
2. Identify an initial set of chapters that should receive priority attention, with the aid of those helping in the editorial process, especially the Managing Editors, and those on the editorial boards for Parts 1-5 of the virtual book, along with guidance from the Advisory Board. These priorities should reflect those disciplines that have the largest numbers of students (e.g., Biology, Communications) as well as those with the closest ties with computing.
3. Organize three workshops, so that the editorial groups can work on their chapters and parts, as well as share best practices and information of interest to multiple groups, and so the Evaluator and Advisory

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Board can review progress and help guide the project to serve its target audience and to prepare the highest quality curricular guidelines.

4. Have productive meetings of the various groups and committees, encouraging brainstorming, planning future activities, providing feedback, and making suitable decisions with regard to deliverables and future work.
5. Enable those involved in editorial work to find existing curricular guidelines that are relevant, to identify syllabi and other resources that aid project activities, to adapt materials they personally have developed, and to work with others to draft new guidelines reflecting their expertise and the group consensus. Curricular modules will follow the template shown in Table 1, which is adapted from a highly success NSF funded curricular development project covering digital libraries, led by the PI and including the Evaluator. The guidelines as a whole will have a structure similar to CC2001, or other related curricular documents. In addition to modules (that will be at the level of a lecture or class unit), they will include sample syllabi, a graph of prerequisite relationships, a summary of the body of the knowledge, description of each part of that body of knowledge, pedagogical comments, and a comprehensive bibliography. See Figure 2 for a simple illustration.
6. Report periodically to ACM and IEEE-CS, so that our efforts fit into their curricular development activities and so that project deliverables can be published and disseminated with their assistance.
7. Test some of the modules developed in courses taught by those involved in the project, or by making a guest appearance in a course taught by another. (Evaluation related will wait for a future funded project, since two years is too short a time for many of the new modules to be used repeatedly.)
8. Spread the word about project activities and results, through the web site, through publications and presentations, through discussions with interested disciplinary societies, and whenever meeting with other interested educators.
9. Develop long-term sustainability plans for the overall project, working with ACM, IEEE-CS, and others at the sites of those involved in the project, so there is broad-based institutional support, and so the virtual book can be expanded and updated into the foreseeable future.

Outcomes:

Our project outcomes are:

1. The virtual book, organized as per Figure 1, with guideline content as per Figure 2.
2. The editorial organization, also shown in Figure 1 and discussed throughout this proposal.
3. Publications and presentations related to 1 and 2.
4. Deployment of the curricular guidelines throughout the nation and the world, in as many as possible of the colleges and universities and programs and courses where there is interest in CT.

Intellectual Basis / Related Work:

Computing Concept Categories: To help ensure that our work is grounded in what educators find relevant, we prepared an online survey. The survey garnered more than 25 endorsements of our proposal idea. Of the respondents, about half agreed to serve in the editorial organization. Figure 3a shows the spread of computing areas covered by the survey group. Figure 3b shows the range of non-computing area covered by that group. Table 2 gives details on the most relevant computing concepts identified.

Coupling feedback from the survey, with data collected from the LIKES workshops, and reflecting discussion at the NRC workshop in February 2009 on Computational Thinking, we have identified four clusters of computing concepts (see also related discussion in Figure 4):

1. Data, information, and knowledge—including their representation and management, and including data structures, databases, document collections, and knowledge management
2. Algorithms, analysis, problem solving, programming, work flows, and software engineering
3. Interaction, interfaces, graphics, games, visualization, and virtual environments
4. Modeling and simulation

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Editor-in-chief: Edward A. Fox; Advisory Board: Lillian Cassel, Steve Cunningham, Mark Guzdial, John Impagliazzo, Andrew McGettrick, Stephen Seidman, Heikki Topi

I. Introduction

Managing editor(s): Weiguo Fan, Steven D. Sheetz

Editorial board: Ghaleb Abdulla (LLNL), Peter Henderson (Butler U.), Harry Hochheiser (Towson U.), Barbara Zimmerman (Villanova)

A. General structure

1. **Acknowledgements: contributors, sponsors, collaborating partners**
2. **Target audience; Motivation, challenges; Purpose, goals, objectives**
3. **Supplementary materials outside this book; Structure of this book**

B. Computing areas connected most frequently with Other Disciplines

1. **Content: data, information, and knowledge - including their representation and management, and including data structures, databases, document collections, and knowledge management**
2. **Processing: algorithms, analysis, problem solving, programming, work flows, and software engineering**
3. **Interaction/visualization: HCI, interfaces, graphics, games, visualization, and virtual environments**
4. **Modeling and simulation**

II. Performing Arts

Managing editor: Christine M. Nass; Editorial board: TBD

Coverage: Dance, Music, Theatre, Visual Arts

III. Languages and Humanities

Managing editor: Trudi J. Abel; Editorial board: Valerie Barr (Union College), Judith Kirkpatrick (English)

Coverage: English, History, Languages, Linguistics, Literature, Philosophy, Religion

IV. Natural Sciences

Managing editor: Robert M. Panoff; Editorial board: E. Hambruch (Purdue), Jessen Havill (Denison U.), Christoph M. Hoffman (Purdue)

Coverage: Biological Sciences, Chemistry, Earth Sciences, Physics

- A. **Biological Sciences** - Editorial board: Anne Boettcher (U. S. Alabama), Bruce Kirchoff (UNC Greensboro), Jamie Kneitel (CSU Sacramento)
- B. **Chemistry** - Editorial board: Clyde Metz (College of Charleston)
- C. **Earth Sciences: Ecology, Environmental Science, Geology** - Editorial board: Denny Fernandez del Viso (U. Puerto Rico, Humacao), Patricia A. Medvick (N. New Mexico College)
- D. **Physics** - Editorial board: Bruce Mason (U. Oklahoma)

V. Social Sciences

Managing editor: Andrea L. Kavanaugh; Editorial board: Joyce Rudinsky (UNC-CH)

Coverage: Anthropology, Archaeology, Communications, Economics, Gender studies, Geography, Political Science, Psychology, Sociology

- A. **Anthropology and Archaeology** - Editorial board: Samuel Collins (Towson U.), Edward A. Fox
- B. **Political Science** - Editorial board: Craig L. Brians (Virginia Tech)
- C. **Psychology** - Editorial board: Steven D. Sheetz

VI. Professional and Other Disciplines

- A. **Business** - Editorial board: Wingyan Chung
- B. **Education** - Editorial board: Colleen Lewis (UC Berkeley)

VII. Future Work

- A. **Dissemination**
- B. **Broader engagement**

VIII. Appendices

- A. **Workshop Reports** - Editors: Wingyan Chung, Edward Carr, Robert E. Beck
- B. **Evaluation Report** - Managing Editor: Barbara Wildemuth

Figure 1. Editorial Structure of *Curricular Guidelines for Computing and Other Disciplines*

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Table 2. Four computing concept categories mapped to ACM Classification System as well as their application examples.		
Computing Concepts	ACM Classification	Examples
Algorithms, processing, analysis, work flow, programming languages	<p>D. Software</p> <ul style="list-style-type: none"> - D.3. Programming Languages <p>F. Theory of Computation</p> <ul style="list-style-type: none"> - F.2. Analysis of Algorithms and Complexity Problem 	<p>Architecture: Generative systems</p> <p>Geography (GIS): Correction algorithm for remotely-sensed images</p> <p>Business: Risk analysis, Excel scenario analysis; financial data mining; mining Web data for business intelligence; classification algorithms for market segmentation; text classification & summarization algorithms</p> <p>Communication: Applying graph algorithms to communication pattern analysis</p>
Data, information, knowledge	<p>E. Data</p> <ul style="list-style-type: none"> - E.1. Data Structures - E.2. Data Storage and Representation - E.3. Data Encryption - E.4. Coding and Information Theory <p>H. Information Systems</p> <ul style="list-style-type: none"> - H.1. Models and Principles <ul style="list-style-type: none"> -- H.1.1. Systems and Information Theory - H.2. Database Management - H.3. Information Storage and Retrieval 	<p>Architecture: Energy, lighting, cost and symbol libraries</p> <p>Geography (GIS): Vector, raster, networks, meta data; GIS database design and development, SQL queries</p> <p>Business: Market basket analysis; customer satisfaction data processing; user-generated Web content analysis; enterprise feedback management</p> <p>Communication: Social interaction data</p>
Graphics, visualization, games, HCI	<p>H. Information Systems</p> <ul style="list-style-type: none"> - H.5. Information Interfaces and Presentation <ul style="list-style-type: none"> -- H.5.2. User Interfaces (D.2.2., H.1.2., I.3.6.) <p>I. Computing Methodologies</p> <ul style="list-style-type: none"> - I.3. Computer Graphics <ul style="list-style-type: none"> -- I.3.4. Graphics Utilities -- I.3.7. Three-Dimensional Graphics and Realism <p>K. Computing Milieux</p> <ul style="list-style-type: none"> - K.8. Personal Computing <ul style="list-style-type: none"> -- K.8.0. General (Games) 	<p>Architecture: Animation, presentation</p> <p>Geography (GIS): Cartography, scene visualization; Finding Malaria hotspots</p> <p>Business: Business intelligence system dashboard; animation in online advertisements; BI visualization</p> <p>Communication: visualizing online communities; mapping Facebook friends; plotting and aggregating network data; studying media richness in CMC</p>
Modeling, Simulation	<p>I. Computing Methodologies</p> <ul style="list-style-type: none"> - I.6. Simulation and Modeling <ul style="list-style-type: none"> -- I.6.2. Simulation Languages -- I.6.3. Applications -- I.6.4. Model Validation and Analysis -- I.6.5. Model Development -- I.6.6. Simulation Output Analysis -- I.6.7. Simulation Support Systems -- I.6.8. Types of Simulation 	<p>Architecture: Thermal simulation, 3D modeling, building information models</p> <p>Geography (GIS): GeoSim educational modules, simulation for long-term effects of infrastructure development; vehicle traffic modeling in urban area; modeling soil erodability and land habitability</p> <p>Business: Virtual business experience (computerized business simulations and exercises) for human resource training; stock trading simulation; EBay auction simulation; inventory modeling; supply chain modeling</p> <p>Communication: modeling social network formation and evolution</p>

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From one perspective this can be summarized as: content, processing, interaction/visualization (input and output), and modeling/simulation (e.g., prediction). Table 2 provides detail about this breakdown. The first column shows our four clusters of computing concepts. The second column shows some ACM categories relating to the broader concept. The third column identifies, in a representative set of other disciplines, where the corresponding computing concepts apply. Thus, we show many contexts in other disciplines where computational thinking is especially appropriate, and give details on which of the many areas of computing need to be understood.

Prior Computing Guidelines:

We will build upon the many related curricular efforts, largely sponsored by ACM and/or IEEE-CS [1, 8, 19, 22, 32, 38, 39, 40, 56, 61, 83, 85]. Members of the project team have been involved in CC2001 and other curricular development efforts [23, 24, 25]. Advisory Board members were key leaders in this.

Prior Guidelines Connecting Computing with other Disciplines:

The topical organization shown in Figure 1 is based on our analysis of a variety of sources. See:

- http://nces.ed.gov/programs/digest/d07/tables/dt07_268.asp,
- http://en.wikipedia.org/wiki/List_of_academic_disciplines
- http://en.wikipedia.org/wiki/Joint_Academic_Classification_of_Subjects,
- http://www.repertoire-recherche.gouv.qc.ca/i/rrp/discipline_en.pdf.

As we develop curricular guidelines related to these other disciplines, we will be guided by prior related work. Identifying this will be a key part of the start-up activity for each Part of the book, and for each Chapter in each Part. In the interest of space, we provide below just a sampling of what we already have identified.

Within the **arts**, and focused on music, we will build on the observations that:

- Music notation and sound can be fully represented digitally.
- Many music educators are using computers to draw students into their programs.
- Technology allows students to create music without being limited to the use of traditional instruments.

These ideas have been incorporated into a number of courses, but in many cases the computing technology has not been strongly connected to CT. Some of the course ideas include: Multimedia Authoring, which covers the creation of multimedia for the music classroom. The music classroom occurs at all levels and we propose to address activities that fit in K-12, in the college classroom with courses for the general student, and in the programs for music majors; Interactive Internet Authoring, which covers the creation of interactive Internet sites for the music classroom; and Digital Media, which covers the creation of multimedia files that may be integrated into Internet and multimedia projects, computer programs, or that may stand alone as educational products (videos, CDs, audio tapes, etc.).

In the **humanities**, the amount and qualitative nature of information to be processed in many disciplines, e.g., history, suggest that students could benefit from substantive understanding of knowledge management techniques. Complex reasoning required to build logical arguments can be represented as concept or cognitive maps, providing an approach for collaborating when developing and evaluating arguments. The “unstructured” nature of the interactions in many humanities disciplines has limited the adoption of technology in past generations. However, with the breadth of information now available through the internet, the potential for students to embrace higher levels of understanding through the integration of ideas has grown dramatically, influencing the meaning of learning in these disciplines.

In the **natural sciences**, the dynamic nature of interactive numerical models that closely simulate

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natural phenomena enable student exploration across disciplines through analogous processes. Thus, the fundamental model of interaction is common across sciences: two objects interact in some way, and one of the objects acquires a property of the other object. In physics, it could be two particles, which after a collision exchange momentum. In chemistry, two molecules interact exchanging an electron. In biology, a healthy person meets a sick person and both leave the interaction with the virus, similar to the interaction of a burning tree adjacent to a tree not (yet) on fire: if they are close enough, with the instrumentality of wind, both trees burn. In developing a dynamic, interactive model of these related processes, there are clear guidelines for addressing these in a curricular context that can be shared across disciplines. [37, 64]

Although there are typically many different disciplines found in today's colleges of **social sciences**, a number of concepts and commonalities exist across these disciplines: Identity [84], context, time and space in social life, critical theory & power [29], agency, social structure, socialization and enculturation, and human relationships [89]. The grand challenges in integrating computing concepts into social sciences include a lack of knowledge of computing concepts that will enable students to analyze real data, understand complex social phenomena, and appreciate difficulties in solving large-scale social problems. The disciplines in social sciences deal with the study of humans and social groups relating to each other. As data about human relationships and social groups are widely available through the Internet and other computing devices, and as the technology has diffused throughout the general population, the relationship between the computing and social sciences disciplines has grown stronger (see Figure 5). Trends include:

- Computing impacts and enables various social activities including interpersonal relationships [21], group interaction and collaborative processes [45, 67, 81], and mass behavior such as social mobilization [41];
- Computational thinking may support students' progressive understanding from micro-level (individual) behavior to macro-level (social) phenomena;
- Computing concepts may help students break down macro-level abstract concepts into concrete behaviors;
- Ubiquitous computing enables the automated large-scale collection, storage, and analysis of social data.

Current State:

Undergraduate education related to the six project partners is going well; we represent leading universities scattered around the nation, of varying sizes, some private and some public, several with large communities from under-represented groups. In addition, the Shodor Foundation works closely with undergraduate programs at nearby universities, such as Duke.

With regard to this proposal, the most relevant information is about our ongoing effort entitled "Living in the KnowEdge Society (LIKES) Community Building Project", an NSF CPATH project that aims to build a community that will define a socially-relevant way to make systemic changes in how computing and IT concepts are taught and applied in both computing and other fields. The end of this two-year effort should occur in the fall of 2009. As per instructions in the NSF call, we "provide institutional data to document the current environment by uploading data into the Supplementary Docs section in FastLane." Please see there a full page table entitled "List of LIKES workshop attendees" that has names of those attending our 4 workshops, grouped into the major areas of the proposed virtual book of guidelines. Also see there, one for each of the 4 partner sites, a summary of the state resulting from LIKES efforts, on pages with title "Current State Supplement - Results at ...".

Implementation Plan

Activities

This project involves collaborative work that ultimately will involve perhaps 100-150 people. We already have about 25 people serving as co-PIs, GRAs, or members of the Advisory Board. Yet more are identified in Figure 1, which describes the editorial structure and lists people who have agreed to assist in various roles. The table on "List of LIKES workshop attendees" in Supplementary Documents describes participants in the previously held LIKES workshops; many of those will help too. Further, there are more than a dozen who participated in the Multidisciplinary Collaboration group from the 2009 Rebooting Computing Summit, and they are committed to assist. For example, in June 2009, at a workshop

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organized by Jessen Havill (Denison University, a member of the Rebooting Multidisciplinary group), including about 30 faculty from all the sciences at top liberal arts colleges¹, other volunteers will be invited to join the editorial team.

Guideline Examples

We will develop curricular guidelines largely in the form of modules. Generally, smaller is better, since adoption and adaption are much easier. Figure 2 shows our well-tested template for modules.

Data analysis / statistics deals with the fundamental skills of exploring and analyzing data. Many times, it requires a student to be able to use some simple statistical techniques such as t-test, correlation, and regression. But better is for students to gain a deeper understanding of the data: the range, distribution, overall trends, outliers, etc.

Information management deals with how to manage the data and information a student collects or gathers over time. Learning objectives include:

- How to effectively formulate queries and search in different knowledge/data bases
- How to represent and organize data into a collection or database
- How to classify and categorize data and information
- How to index information for search
- How to build an taxonomy and use it for browsing and cataloging
- How to use SQL to perform effective data extraction and transformation

Mod/sim involves the fundamental scholarly practice of developing suitable models for reality or artificial realities. Due to coupling it with simulation, in the context of CT, the model must have a computational aspect, so that system performance can be simulated, allowing prediction. Key concepts include:

- Discrete Events; Event-based simulation
- Modeling with PDEs; Dynamic modeling with PDEs or Agent-based modeling

Figure 4. Curricular comments related to Part 1, about computing areas

The following topics in the discipline of communication have strong potential to integrate computing concepts: 1. Social Networks, 2. Technology Diffusion, 3. Interpersonal Computer Mediated Communication, 4. Computerized Information Seeking, and 5. Online communities. An example integration is shown below using Social Networks.

Topic: Mapping social actors from their interaction data – sophomore level

Learning Objectives:

- To understand how and why social network technologies connect people
- To analyze social network data using computing tools and methods
- To visualize social network data

Learning Approaches: activity-based, PBL

- Data collection from Facebook
- Relating elementary graph theory concepts and terms to the topic
 - Nodes and links, actors and relationships
 - Metrics: degree, density, degree distribution, centrality
- Qualitative Analysis: popularity, communication pattern, relationship type
- Applying visualization tools to represent the data

Student Activities:

- Mapping your friends from Facebook data
- Plotting network data using Excel graph wizard
- Interview/discuss with social actors to reveal different types and strengths of relationships

Figure 5. Curricular components related to communication

One of the relevant learning communities is the broad population of undergraduate students who want a general exposure to computing. While we believe it best to learn in context, in some institutions there

¹ <http://www.denison.edu/academics/departments/mathcs/mellon2009.html>

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are general education courses that will be all about computing, or will have some computing aspect. In such cases, and in other similar cases, courses about key computing concepts are most appropriate. Figure 4 presents some illustrative information related to the coverage planned in Part 1. Another learning community is those interested in communication; see the examples and discussion given in Figure 5. Raising the level of granularity of the discussion, Figure 6 shows some guidelines for Part 5, Social Sciences.

The disciplines in social sciences deal with the study of humans and social groups relating to each other. As data about human relationships and social groups are widely available through the Internet and other computing devices, the relationship between the computing and social sciences disciplines is growing stronger than ever. A number of trends can be observed.

- Computing impacts and enables a variety of social activities including interpersonal relationships, group processes, and mass behavior
- Computational thinking may support students' understanding to move from micro-level behavior to macro-level phenomenon
- In addition, the use of computing concepts may help students break down macro-level abstract concepts into concrete behaviors
- Ubiquitous computing enables the automated large-scale collection, storage, and analysis of social data

Figure 6. Curricular comments related to Social Sciences

Project milestones

As can be seen in the Timeline, in Supplementary Documents, our project will run for two years starting 1/1/2010. Other than when the project starts and ends, the most important other events are the workshops

1. March 2010, Santa Clara University – hosted by Wingyan Chung
2. October 2010, NC A&T University – hosted by Ed Carr
3. July 2011, Villanova University – hosted by Robert Beck

At these events, members of the editorial boards and the Advisory Board will meet.

Dissemination Plan

To ensure the success of our project and disseminate the results from our efforts, we will engage in various activities for dissemination:

1. A project website will be set up for immediate release of all deliverables as soon as they are available. The final book from this project will be integrated into the NSF NSDL Ensemble pathway project (www.computingportal.org) for long term archiving and dissemination.
2. We will present our results at various conferences and workshops on computing education and application such as SIGCSE, AMCIS, SIGITE, CCSC, FIE, etc. Handouts, flyers will be prepared and distributed at these conferences. Editorial board members will disseminate to other disciplines.
3. We will work with ACM and IEEE-CS to publicize our efforts. See promise of support in the Supplementary Documents section.
4. We will disseminate our efforts and the resulting virtual book through many listservs, to reach out to diverse communities that are interested in computing.
5. LIKES workshop attendees will assist as liaisons for targeted dissemination. Many of our workshop attendees have expressed their interest in helping and continuing to work with our new efforts.

Collaboration and Management Plan

This two year project involves 11 co-PIs at 6 institutions; Dr. Wildemuth, the outside evaluator, will function independently, with strong support, including funding amounting to close to 15% of the overall

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project budget. In addition, there are 7 people serving on the Advisory Board (leaders in the international scene, of the field of computing education). There will be three in-person gatherings, referred to as workshops (since they are working meetings), involving these and the various editors helping with the project. In addition there will be many electronic meetings.

Collaboration will be focused around the workshops, but there also will be some local gatherings; note that Duke, NC A&T, Shodor, UNC-CH, and VT are all fairly close together. In addition there will be meetings at ACM SIGCSE and at other events (whenever more than 2 people involved in the project are together). We will propose workshops at conferences, and when those are approved, will have the key people from the editorial organization focusing related efforts around those meetings.

Many of the collaborators have worked together, in various groupings, and are comfortable connecting through electronic methods. We will make liberal use of phone calls, conference calls, videoconferences, Skype sessions, wikis, listservs, web sites, digital libraries, and support systems like Sakai.

The three chairs of workshops will serve as the Workshop Committee, and will have a monthly electronic meeting to plan the upcoming workshops, and to finalize reporting of prior workshops.

Much of the organization of the project relates to the editorial structure of the planned virtual book, as was discussed earlier, and is illustrated in Figure 1. For example, for parts 1-5, the Managing Editors will convene a 1-hour electronic meeting (e.g., with Skype) each month of the project, for all serving on the editorial boards for that part. In some cases, when there are a number of people working on a particular chapter, the lead person for that chapter effort will convene a monthly (electronic) meeting of those involved, and will represent that group for the meetings for their Part of the book. The Managing Editors and the Editor-in-Chief, along with the Workshop Committee, will constitute the Executive Committee, which will have a monthly electronic meeting. As is explained below, the Evaluator will participate in project meetings, and help the team to improve project processes.

Following are brief descriptions of the 11 co-PIs and their roles in the project. Then there are brief comments on the 7 members of the Advisory Board.

Trudi J. Abel will be Managing Editor for the Humanities part of the planned book. As the director of the Digital Durham project (<http://digitaldurham.duke.edu>) at Duke University, Dr. Abel has worked in digital history for more than a decade, collaborating with Durham Public Schools teachers, and Duke graduate and undergraduate students, while mentoring high school apprentices and interns at the Shodor Education Foundation. She is also the creator of an innovative undergraduate research service learning class called “Digital Durham and the New South” where undergraduate students themselves mentor eighth graders in using computers to research and write the history of their community.

Robert E. Beck will create and convene the culminating workshop at Villanova, building on the results of previous workshops and online conferences. He will assist the Managing Editor for the Arts curriculum, using his breadth of contacts. Professor Beck has served as department chairperson of Computing Sciences at Villanova since 1992. In this role he has led a number of initiatives to bring computing to all students and in a variety of contexts. He initiated the discussions with the Psychology, Philosophy, and Biology Departments that resulted in the creation of Villanova’s concentration in cognitive science. More recently he has team-taught a course in computational molecular biology that is serving as the stimulus for a new degree program in bioinformatics. His earlier work on courses for liberal arts students led to papers and presentations at the World Conference on Computers in Education and the SIGCSE Technical Symposium. He serves as the liaison from SIGCSE to the Disciplinary Societies Forum, and to the Preparing Faculty for the Future program of the Association of American Colleges and Universities.

Edward C. Carr will be the host of the project's second workshop, at North Carolina A&T University. He also will support the organization of the two other workshops. He is an assistant adjunct professor in the Department of Computer Science at North Carolina A&T State University. He has over 20 years experience teaching in both Computer Science and Mathematics. His teaching career has spanned both the community college and university levels. He has been active in both Mathematics Education as well as Computer Science Education. His main research areas are Hamiltonian Cycles in digraphs, Constraint

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Satisfaction Problems, and Web Engineering. A co-PI of the LIKES project, Professor Carr was the host of the second LIKES workshop held in April 2008. He has published 13 referred journal publications and is a Fellow of the Institute of Combinatorics and its Applications. As a result of LIKES, he has team-taught a Web Science course that will be a cornerstone for the new degree program in Web Engineering.

Wingyan Chung will be the host of this project's first workshop, to be held at Santa Clara University in March 2010. He will lead the various efforts in the SCU workshop, support the organization of the other workshops in this project, and contribute to the virtual book. Professor Chung is an assistant professor in the Department of Operations and Management Information Systems in the Leavey School of Business at SCU. A co-PI of the LIKES project, Dr. Chung was the host of the first LIKES workshop held at SCU in December 2007. He has published more than 50 refereed articles in the areas of computing and IT education, Web searching and browsing, data/text/Web mining, and business intelligence [6, 9, 11, 12, 13, 14, 15, 16, 17, 18].

Weiguo Fan will help on the introductory part of the book as well as working with other science disciplines to define model curriculums. Professor Fan, of Virginia Tech's Department of Accounting and Information Systems, has worked as a co-PI on the prior related CPATH grant, LIKES. He has expertise on the introduction to information systems/technology to business majors and has published more than 90 papers on information systems and information technology related topics.

Edward A. Fox will direct this project, and serve as editor-in-chief. He is a Professor in the Department of Computer Science, Virginia Tech, and PI on the LIKES project. He directs the Digital Library Research Laboratory. Fox has been PI or co-PI on more than 100 research grants. He has had grants or publications connecting with biology, chemistry, physics, social work, and archaeology [2, 26, 62, 68, 80, 86, 87]. He is on the steering committee for the ACM/IEEE and the Asian digital library conferences, and has served on advisory boards for UK and European digital library initiatives. He was the first chair of the NSDL Policy Committee. He is a member of the Executive Committee on the Ensemble Computing Pathway in NSDL; he is responsible for the Ensemble distributed portal (www.computingportal.org). Fox serves as Executive Director for the Networked Digital Library of Theses and Dissertations (www.ndltd.org), helping make electronic theses and dissertations readily available worldwide.

Andrea L. Kavanaugh will be Managing Editor for the Social Sciences part of the planned book. Dr. Kavanaugh, a Fulbright and Cunningham Fellow, is a Senior Research Scientist and Associate Director of Virginia Tech's university-wide research Center for Human-Computer Interaction (HCI). As such, and in her prior position as Director of Research for VT's community computer network known as the Blacksburg Electronic Village, Kavanaugh has been leading and collaborating on interdisciplinary research for over a decade. She is the author or editor of several books on the use and social impact of computing. She has been the PI or Co-PI on numerous grants from NSF and the US Department of Commerce, and currently leads an NSF grant on the use and social impact of mobile phones during the tragic shootings at VT in 2006. She heads the social computing lab at the HCI Center. She currently serves on the Board of Directors of the Digital Government Society of North America, and is a past member of the Board of the International Telecommunications Society.

Christine Nass will be Managing Editor for the Arts part of the planned book. Ms. Nass is an Adjunct Faculty member teaching music courses for the Honors Department at Villanova University. She maintains a Music Technology Mac Lab used for teaching, digital audio recording, sampling, and music production at Villanova. Ms. Nass is a professional opera singer and has performed internationally. She has assisted with the editing of several books on technology guidelines for music education [31, 55].

Robert M. Panoff will serve as Managing Editor for Natural Sciences. Continuing an active research program in condensed matter physics, Dr. Panoff and Shodor were named by NSF as foundation partners in the revitalization of undergraduate education. His founding and leadership of the National Computational Science Institute garnered the highest award for undergraduate computational science education from the U.S. Department of Energy. Dr. Panoff is the author and editor of many digital works

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in science, mathematics, and education, and he directs the Computational Science Education Reference Desk, a Pathway portal of the National Science Digital Library (NSDL). He brings to the overall project a special focus for materials that promote inclusion of visual and hearing impaired learners.

Steven D. Sheetz will work on the database, information, and knowledge area of the introductory part of the book and apply those concepts across the range of disciplines participating to define model curriculums and develop modules that implement database related concepts. Professor Sheetz, of Virginia Tech's Department of Accounting and Information Systems and Director of the Center for Global Electronic Commerce in the Pamplin College of business, has worked as a co-PI on the Living In the KnowlEdge Society (LIKES) a prior related CPATH grant. He has studied the learning of object-oriented systems and taught a variety of topics in information systems.

Barbara Wildemuth will serve as the external evaluator for the project. In this role, she will have primary responsibility for the evaluation of both the processes supporting the development of the guidelines and the outcomes of that development effort. Dr. Wildemuth also will be responsible for the management of all (evaluation) work conducted at UNC-CH. She has both a formal education and significant professional experience related to evaluation, described in more detail in the evaluation plan.

Advisory Board

Guidance for the project will come from an advisory board whose members have made significant contributions to the breadth of computer science education. Their service to organizations seeking to make substantial changes in the nature of education in computing and in the diversity of the audience will provide the current project with essential benchmarks to insure its success. The board includes:

- Lillian (Boots) Cassel, Professor of Computing Sciences, Villanova University: CITIDEL, Ensemble, SIGCSE lifetime service award, member of the ACM Education Board and Education Council, NSDL Policy Committee Chair
- Steve Cunningham, Gemperle Distinguished Professor of Computer Science emeritus, California State University, Stanislaus: former chair of ACM SIGGRAPH, member of the Education Committee of Eurographics.
- Mark Guzdial, Professor, School of Interactive Computing, Georgia Tech: leader in the developing field of media computation, member of the advisory board of the Anita Borg Institute, member of the ACM Education Board and Education Council, leader of Georgia Computes!
- John Impagliazzo, Professor Emeritus, Hofstra University: member of the ACM Education Board and Education Council, founder and past chair of the ACM Two-Year College Committee
- Andrew McGettrick, Professor of Computer Information Systems, University of Strathclyde: Chair of the ACM Education Board and Education Council, SIGCSE lifetime service award
- Stephen Seidman, Dean, College of Natural Sciences and Mathematics, University of Central Arkansas: member of the Board of Directors of CSAB (formerly known as the Computer Science Accreditation Board), past member of the Board of Governors of the IEEE Computer Society
- Heikki Topi, Associate Professor of Computer Information Systems, Bentley College: member of the ACM Education Board and Education Council, member of the ACM/AIS/AITP joint task force for *IS 2002*, the undergraduate information systems model curriculum, member of the ACM/AIS/IEEE-CS task force that created the *CC2005 Overview Report*.

Evaluation Plan

We will undertake a multi-faceted evaluation of the curricular guidelines being developed in this project, assessing both the process of developing the guidelines, and the product that results. Two aspects of the development process will be examined: the breadth and diversity of the project participants, since they are critical to the successful adoption of the guidelines; and the effectiveness of the workshops. The curriculum guidelines themselves will be evaluated in relation to their quality (assessed through expert review) and the likelihood they will be adopted (through an experimental study of their potential impact).

Process evaluation: Breadth/diversity of participants. A national curriculum development effort can be considered successful only if it is eventually adopted by a significant number of colleges and

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universities. One of the barriers to such widespread adoption is instructors' beliefs about whether their interests were well-represented during the process of developing the curricular guidelines. While we will not be surveying instructors during the course of the guidelines development, we will assess the breadth and diversity of the participants in the project work. We will interpret this diversity as an indicator of the project's ability to represent the views of college and university instructors, generally.

There are many ways that people will become involved in this project. Project team members will be the most active participants. Each disciplinary lead will recruit and involve a number of other leaders in the respective disciplines; each of these key volunteers will be contributing directly to the development of the curricular guidelines. In addition, it is likely that the volunteers and project team members developing specific chapters will call on their colleagues to comment on their work and to provide additional ideas.

During the course of the project, we will collect a complete list of the participants, both team members and volunteer participants. For each person, we will record his/her name, institutional affiliation, Carnegie classification of the institution, location (city, state), gender, race/ethnicity, disciplinary specialization, and role(s) in the project. We also will ascertain if they or their colleagues intend to deploy any of the curricular guidelines in their own teaching activities, or in local courses or programs. Based on our experience with a previous project [3, 4, 27, 33, 34, 35, 63, 65, 66, 74, 75, 76, 79, 91, 95] in which almost 100 people have participated in the development of a curriculum on digital libraries, we would expect that 150-200 people from a variety of institutional settings will be involved in this project over the course of the two-year project period. If we find that the pool of participants is not representative of the project's stakeholders, we will meet with the co-PIs to discuss ways in which this problem can be remedied.

Process evaluation: Workshop effectiveness. To evaluate the effectiveness of the process by which the project team works together, we will directly observe the workshops and will interview team members concerning the processes used to develop guidelines. Project team members will meet regularly to work on the guidelines. We will observe these workshops and, after each, will ask the participants to provide a quick evaluation of the meeting's success in achieving its objectives. The evaluation will consist of a one-page survey, including both rating scales and open-ended questions related to the meeting's success. We will follow up with participants willing to discuss their evaluation more thoroughly.

In addition, we will regularly interview the project co-PIs (i.e., those responsible for particular parts and chapters², as well as PI Fox) concerning the project's work processes. These interviews will cover both the problems that have surfaced and the most effective methods that the team has developed for accomplishing their goals.

The results of these two types of evaluations will be reported to the project team in two ways. First, any concerns raised about the processes within the project team will be discussed with the relevant project co-PIs, and suggestions for improving the process will be provided. Second, best practices identified in one part of the team (e.g., a group working on a particular chapter) will be communicated to the rest of the project team. In this way, the entire project team will benefit from what we learn in this evaluation.

Product evaluation: Expert review. We have proposed to evaluate the project's processes because we believe that they have a strong effect on the overall outcomes of the project. Even so, we will place particular emphasis on the evaluation of the guidelines themselves, and their potential for influencing the incorporation of Computational Thinking (CT) into the curricula of a variety of disciplines.

The first of two evaluations is expert review of the draft guidelines. It is expected that individual part and chapter teams will have fairly complete drafts of curricular guidelines available midway through the second year of the project. At that point, we will undertake expert review of those drafts. Five to ten instructors/scholars will be recruited to review each part and each chapter. These reviewers will be well-established in their home disciplines, as well as being interested in the incorporation of CT within that discipline's instruction. They will be identified through literature searches and suggestions from project team members, or from our growing contact lists arising from the unfolding of the Rebooting Computing

² The development process for each chapter, with guidelines, will be analyzed. For each part there are two processes to be analyzed; one is for the group working on guidelines that are at the part level but not connected with any particular chapter. The other is the overall process for the entire part, including all the chapters.

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initiative or from the LIKES and other CPATH project workshops; we will not include any of those who have been involved in chapter development. Each reviewer will be asked to examine one part or chapter, commenting on its coverage of the topic, its inclusion of Computational Thinking, and its potential usefulness within a specific department/school. In addition to evaluating the part or chapter, each expert will be asked for suggestions for improving it. A wiki will be used to support this expert review process, as was done successfully in an earlier project [33]. Use of a wiki will foster communication among the evaluators working on a particular chapter, allowing them to respond to each other's comments.

Product evaluation: Experimental study. The product evaluation also will include an experimental study of the potential for adoption and use of the guidelines being developed. The study will be conducted near the end of the project, using a posttest-only control-group design [5]. A sample will be selected by compiling a list of scholars publishing on educational issues in the relevant disciplines; we will include 10-12 scholars in each of the relevant discipline groupings (e.g., humanities), for a total sample size of 40-48 study participants. We will exclude those who participated in any way in the development of the guidelines or who have had prior knowledge of them. We will continue to recruit participants until the minimum sample size has been achieved. Participants will be randomly assigned to two groups. One group will be interviewed about the incorporation of CT into their discipline's instruction/curricula; they will be asked to assume that no curricular support would be available for such an effort and that each instructor or university would need to develop their own curricular materials (i.e., the situation that exists currently and will continue to exist unless this project is funded). The other group will be asked the same questions, but will be introduced to the guidelines developed for their disciplines. These structured interviews will be conducted by phone, and then transcribed for analysis. The results will be a clear indicator of the potential impact of the curricular guidelines, and so will serve as a summative evaluation.

Working with the Advisory Board. Since the Advisory Board is a body of senior people involved in computing-related education, who have experience preparing other sets of guidelines and in deploying such guidelines and other innovations, separate discussions will take place with this group (at each of their three in-person meetings). They will be asked to provide guidance on all aspects of the evaluation. They also will be asked to help make sure that the project team and volunteers involved are refining the project processes and products appropriately, based on evaluation results.

Linkages with other CPATH evaluations. In addition to the evaluation of this project's activities, the evaluation team will participate in a CPATH program-level evaluation and will provide common data to the CPATH program-level evaluator, as requested.

Evaluation team. The evaluation team will consist of Dr. Barbara Wildemuth and one graduate research assistant. Dr. Wildemuth has a strong record of training and experience in evaluation. In addition to her Ph.D. in information systems design and evaluation, she completed a master's degree in educational psychology with emphasis on measurement and evaluation. She frequently teaches courses in social science research methods, and is the author of a forthcoming book on research methods [90]. She planned and managed the evaluation of a similar curriculum development project (<http://curric.dlib.vt.edu/>).

Results from Prior NSF Support

Information on the single most closely related NSF awarded project that each of the PIs has received in the past five years follows:

Beck, Chung, Evia, Sheetz: 8/1/07-7/31/09: NSF CCF-0722259: Collaborative Research: CPATH CB: Living In the KnowlEdge Society (LIKES), \$289,999 to VT, PI Edward A. Fox, Co-PIs: Carlos Evia, Christopher W. Zobel, Steven D. Sheetz, Weiguo Fan, in collaboration with 0722289 to co-PI Edward Carr, North Carolina A&T State University; 0722276 to Robert E. Beck, Villanova University; and 0722263 to Wingyan Chung, Santa Clara University [15, 16, 30, 36, 77, 88]

Carr: 5/1/08-8/1/10: NSF BPC-DP (SGER): Software Design & Development Teams and Tournament; \$179,860; PI: Huiming A. Yu, Co-PIs: Edward C. Carr, Gerry Dozier, Shearon A. Brown

Fan: 9/1/08-8/31/11: NSF DUE-0840719: Collaborative Research: Ensemble: Enriching Communities and Collections to Support Education in Computing (NSDL pathways project); \$135,148 + expected: 146,633+143,221

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(\$425,002 total to VT, with overall total to all partners \$2M); VT PI Edward A. Fox; VT co-PIs Stephen Edwards and Weiguo Fan; with overall PI Lillian Cassel at Villanova [10]

Fox: 9/1/05-8/31/08: NSF DUE-0532825: Personalization of Content: Bridging the gap between NSDL and its users through the course website, \$449,912, PI: Manuel A. Perez, co-PIs: Edward A. Fox, Lillian N. Cassel, and Weiguo Fan [20, 54, 57, 58, 59, 60, 69, 70, 71, 72, 73, 92, 93, 94, 96, 97]

Kavanaugh: 9/1/2004-2/29/2008: NSF Digital Government-0429274: Modeling Online Participation in Local Governance, \$601,980 to VT, PI Andrea Kavanaugh, Co-PIs: Manuel Pérez-Quñones, Philip Isenhour [7, 28, 42, 43, 44, 46, 47, 48, 49, 50, 51, 52, 53, 82]

Wildemuth: 1/1/06-12/31/08: NSF IIS-0535057: Collaborative Research: Curriculum Development: Digital Libraries, \$272,187 to VT, PI Edward A. Fox for this 2 university project (with UNC Chapel Hill, with co-PIs Jeffrey Pomerantz and Barbara Wildemuth) [3, 4, 27, 33, 34, 35, 63, 65, 66, 74, 75, 76, 78, 79, 91, 95]

Summary, Intellectual Merit, Broader Impact

This project will help advance CPATH to the next level, launching a national curricular development activity so Computational Thinking will permeate undergraduate education. We will build upon results of other CPATH projects (including the Rebooting Computing initiative), diverse activities related to CT, and the LIKES initiative, that has been a highly visible part of the first round of CPATH activities. The **intellectual merit** of this work will be to harness all such related work, and the knowledge and insights of over 100 team members and volunteers who will serve as the editorial group to develop guidelines connecting computing and other disciplines, guided by a prestigious Advisory Board. The **broader impact** of this project will result from the diversity in our team and our 6 institutions, but even more by ensuring that CT is learned in context in other disciplines. This ambitious project will make significant strides over two year, and then with ACM and IEEE-CS and volunteer support, sustain and expand this effort into the foreseeable future so as to ultimately cover all popular other disciplines.

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