Technology Fluency
A Teagle Working Group White Paper
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I. Executive Summary

Ten institutions participated in the Teagle Foundation-sponsored project on Technology Fluency from November 2005 through November 2007. The group met three times—hosted by Washington and Lee University, Drew University, and Princeton University. After initial brainstorming discussions, the group took as its primary project the revision and updating of key sections of a seminal early document on the issue—the 1999 report by the National Research Council entitled *Being Fluent with Information Technology*. We posed the question to ourselves: “How can colleges and universities best promote technology fluency within a liberal arts curriculum for our students in 2007?” The group divided into working groups to revise the three key sections of that report, and to develop material for a fourth section on society, values, and ethics. In addition, the group worked as a whole to develop the following set of basic recommendations on the question of technology fluency in higher education:

- Abandon the notion of a “technology fluency” requirement
- Deliver such instruction in a reactive rather than pro-active mode
- Acknowledge that such instruction is best delivered on a “just-in-time” and “need-to-know” basis
- Acknowledge that most such instruction must be individualized
- Encourage project-based learning
- Abandon the attempt to deliver specific “skills” courses
- Encourage elective, rather than required, courses on meta-questions such as the history of technology, societal impact, and ethical issues
• Reconsider Quantitative Reasoning requirements at colleges (typically part of general education although variably labeled) to include multiple key modes of reasoning: arithmetic, algorithmic, computational, data analysis, statistical

• Bolster training for faculty/staff

The following are bulleted summaries of the results of the four working groups updating the components of Being Fluent.

Intellectual Capabilities

1. Engage in sustained reasoning
2. Use language with logical precision
3. Formulate hypotheses, devise appropriate experiments, test possible solutions
4. Use effective troubleshooting strategies
5. Organize and navigate information structures and evaluate information
6. Collaborate
7. Communicate to other audiences
8. Expect the unexpected
9. Anticipate changing technologies
10. Think about information technology abstractly
11. Manage multiple tasks simultaneously
12. Employ visual or aural media to enhance verbal presentation of information and ideas

Fundamental Concepts

1. Computers
2. Networks
3. Digitization
4. Algorithmic thinking and programming
Contemporary Skills

1. Versatile use of computers
2. Mastering major functions and tools of computers
3. Understanding issues and methods of security
4. How to “find information”
5. How to “store information”
6. How to “generate information”
7. How to network
8. How to use virtual environments for learning
9. How to get help

Society, Aesthetics, Ethics, and Values

(This category was not addressed in the 1999 report. Because there was no extant list to update, this working group framed its work in the form of questions.)

1. How has society been transformed through IT?
   i) How has IT changed the political world?
   ii) How has IT changed the economic world?
   iii) How has IT changed the social world?
   iv) How has IT influenced the Arts?
   v) How has IT changed the Sciences?
   vi) How has IT changed education?
   vii) How has IT changed the way we communicate?
2. What IT practices are ethical and what are not?
3. How has IT changed people’s values, perceptions, and actions?
4. How has IT changed social and legal boundaries?
5. How can IT be used to improve society?

6. How might IT harm society?
II. Key Findings

The following key findings to the question “How can institutions of higher education best promote technology fluency?” offer an approach—that is ultimately more descriptive than prescriptive—that we believe can be taken by any institution. They will be elaborated later in this section.

- Abandon the notion of a “technology fluency” requirement
- Deliver such instruction in a reactive rather than pro-active mode
- Acknowledge that such instruction is best delivered on a “just-in-time” and “need-to-know” basis
- Acknowledge that most such instruction must be individualized
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- Bolster training for faculty/staff

We have concluded that institutions of higher education are not proving particularly good at conveying technology fluency, for a variety of compelling reasons.
• The necessary and specific skills needed by students (and faculty/staff) are changing so rapidly.

• The knowledge base and skill set necessary are so individualized, depending upon the work students are doing.

• The academy (at least most faculty and administrators) regards technology more as a tool than as an object of academic investigation.

• The skills are so practically-oriented.

• A “one-size-fits-all” model to “delivering” the skills/knowledge that constitute technology fluency has not worked, does not work, and doesn’t appear than it will ever work.

• Whole courses on the topic of “technology fluency” itself broadly defined typically do not work very well and have not found their way into the general education requirements of most schools.

Abandon the notion of a “technology fluency” requirement

Given the above conclusions, the Teagle group reached consensus that institutions were unlikely to adopt a “technology fluency” requirement. First, there was no agreement among the Teagle participants, although considerable debate, about what specific skills and knowledge set such a requirement must include. Second, as described earlier, there appeared to be little eagerness or will for the individual campuses to engage in the intellectual discussion of the topic nor in the political battles that inevitably characterize the contested ground of general education or graduation requirements.
On college campuses, we encountered many assumptions and convictions, some more valid than others, that militate against the adoption of a technology requirement. These are some of the most prevalent:

- Today, students come to college already proficient, and more comfortable (and adaptable) with technology than the faculty.
- Students pick up what they need when they need it—and, typically, they do so through informal, *ad hoc* means.
- Skills and concepts should be taught as needed, and resources made available when needed throughout the curriculum.
- Help-desks and other extra-curricular support structures can do the job.
- A deep understanding of the principles and science beneath the use of technology, or even a basic understanding just is not necessary in order to use the technology of our everyday and academic lives. (We all use our cell phones and ipods just fine, thank you!)
- Teaching the ethical implications of technology, or ethics of any stripe, is not the business of the academy. Or, if we do address ethical issues, that instruction should be integrated seamlessly into courses on issues and topics within the disciplines rather than taught separately—or…
- Courses on ethics or on the history and impact of technology are well and good, but should be electives, not requirements.

Although members of the Teagle Group themselves did not necessarily subscribe to these beliefs, we came to recognize them as forces—some overt, some subtle—that would make recommending such a requirement both futile and unwise.
Deliver such instruction in a reactive rather than pro-active mode

If we begin by recognizing the extreme spectrum of skills and knowledge that our students bring to campus, even when they arrive as freshmen, then we understand why a pro-active approach to teaching “technology fluency” has little chance of succeeding. Such skills and knowledge vary widely by institution. Obviously, interest and talent matter. Students at MIT will enter with a different level of expertise than will those at a comprehensive public institution. So does geographic location and socio-economic status of the student body vary school to school. And, of course, those variations and differences operate within institutions as much as among institutions.

Therefore, a pro-active pre-packaged delivery option—whether it be full for-credit courses, required self-paced instructional courses, mandatory elements in new-student orientation, etc.—does not appear promising, at least in the higher education setting. (Such instruction at the middle school or secondary level—before those differences develop fully—may indeed make more sense.) With a potential audience with wildly variable skills and knowledge, required courses will serve only a fraction of their students well; for others, the material will either be too familiar or too alien and difficult. And, if a “one-size-fits-all” model will not work, it is equally improbable that a college can afford to provide a sufficient array of courses at different levels and covering different areas adequately to meet the needs of all its students. Segmenting that audience is complicated and expensive; few schools have faculty or staff members properly trained or available to deliver such a variety of courses.

One option is an on-line, self-paced instructional model—which could be required of all students as a condition for higher level work. In fact, the Williams School of Commerce, Economics and Politics at Washington and Lee University has developed and requires such a Information Technology
Literacy course for its prospective majors in Business Administration, Accounting, Economics and Politics. However, it focuses sharply on certain software applications, some academic, some administrative, such as Word, Excel, Access, Power Point, Windows and Novell Groupwise (the W&L email and scheduling software package). Professor Robert Ballenger demonstrated this online course, constructed of both tutoring and testing modules, to the Teagle Group at its first meeting in Lexington. (See the W&L report in Appendix F for a link.) It was well received, but also viewed as quite limited in scope, its objective was to prepare students with a common set of skills so that faculty members could make assignments without having to teach their students these applications. There was also a strong sense that most students would need to relearn, or at least refresh, their knowledge and skills when they confronted an actual assignment that required more than basic familiarity with these applications. If one is not using an application such as Excel or Access all the time on a sophisticated level, it is unlikely that such one-time training will obviate the need for the “trial-and-error” method by which most users accomplish a given task. Indeed, even daily users of a complex program such as Microsoft Word typically “know” only a small percentage of all the available features and commands; users learn those advanced features when they need them.

As we have noted, few schools are rushing to adopt new requirements; schools with such requirements have seen limited success. Instead most schools are focusing resources on bolstering non-classroom support structures to assist students on-demand. The preferred model, rather than pro-active, is reactive.

*Acknowledge that such instruction is best delivered on a “just-in-time” and “as-needed” basis*

*Acknowledge that most such instruction must be individualized*
These two bullets are combined because they represent the key characteristics of such reactive instruction: a version that is suited to individual capacity, training, and need; one that is delivered on a “just-in-time” and “as-needed” basis, whether in person or online. Institutions need to have a flexible and robust program of varied resources, and it is a serious challenge to institutions to provide enough, and the right kind, of such support. The Teagle institutions have created many different models, including online for-credit courses, peer-to-peer tutors, as well as full-service online, phone and drop-in help services. Different models seem to be working well at different schools; there was no data to demonstrate that one prescribed set of such support services was better than another. See the individual institutional reports for more information.

Encourage project-based learning

Although the group rejected the notion of whole courses dedicated to teaching “technology fluency,” we agreed on the value of embedding some of that instruction in courses across the curriculum. Such embedded instruction, typically paired with assignments that require employing certain technological tools, keeps faith with the “just-in-time” and “as-needed” model.

One notion arose independently but universally in all of the working groups as we revised the 1999 document: the model of project-based learning. Again, on the premise that students learn what they need when they put knowledge or skills into practice or when they must design, develop and deliver a product, project-based learning provides the most promising avenue for technology instruction. Assigning complex, often collaborative, projects positions students first to figure out what they need to know, then to learn the requisite skills as they apply them to solve problems, to broaden their knowledge base, and—if designed with such an objective—to address larger questions about epistemology, societal impact, and ethics. Indeed, we believe that well-designed project-based
assignments embedded within courses throughout the curriculum are the ideal model for promoting technological fluency.

This is hardly a new idea. In fact, three pages in the “Implementation Considerations” chapter of the 1999 *Being Fluent* are devoted to “A Project-Based Approach to Developing FITness.” Those pages emphasize what has become a commonly-accepted concept that active learning is more effective than passive learning; the report encourages “instruction as active learning” and “instruction through discovery learning,” and recommends developing “appropriately scoped” projects. Appendix A of *Being Fluent* provides eight examples of such projects, from designing a home budget, to developing a plan for a computer store, and designing a web homepage. These examples may not seem particularly imaginative given the new tools now available and the problems that are now addressable using computer-based techniques. Innovative multidisciplinary projects can be devised that will focus on some of the most important questions of our times, from collecting and organizing data on global warming, to issues of disease and healthcare, to sophisticated financial models for business classes, to economic analyses, to web-based text and image repositories for humanities projects.

The report states: “No single project bestows FITness, but a series of well-chosen projects can provide a foundation for the lifelong journey toward FITness.” The Teagle group heartily endorses the conclusion. However, where the 1999 document includes but does not highlight this point, we hope to make this idea a much more emphatic and central recommendation of this White Paper.
Abandon the attempt to deliver specific “skills” courses

An obvious corollary of the above discussion is that we believe it is inefficient, both in terms of student learning and retention, and it terms of institutional resources, to try to develop and deliver specific live “skills” courses in technology. We also discourage any general overview courses cloaked as an introduction to technology. We would like to believe in the economy of scale such collective instruction should offer, but we do not. In addition, we fear that many specific skills taught in such courses will become obsolete almost as fast as they can be taught. Those resources are better devoted to bolstering the various individualized support structures, online and in person, that the institution can offer its students, faculty and staff. The one possible exception is online skills-based courses that could be ordered up as needed by students, but we see such resources as more closely aligned with our recommendation for reactive models of instruction and support.

Encourage elective, rather than required, courses on meta-questions such as the history of technology, societal impact, and ethical issues

Although we discourage the idea of “skills” courses, we strongly believe that institutions should offer, and provide incentives for faculty members to develop and offer, innovative courses in a variety of disciplines on the history, sociology, economic, and ethical implications of technology of all kinds and contemporary culture’s utter dependence upon it. A number of Teagle institutions offer such courses, and we encourage the further development of genuinely interdisciplinary and novel approaches to the many important issues raised by the ubiquity and centrality of technology. We all need to understand the impact of such technology and to anticipate how society will evolve as a result of the accelerated rate of technological change.
Reconsider Quantitative Reasoning requirements at colleges (typically part of general education although variably labeled) to include multiple key modes of reasoning: arithmetic, algorithmic, computational, data analysis, statistical

In discussion, the Teagle group often focused on the various underlying competencies that contemporary technology demands, and how our understanding of such quantitative and logical abilities have altered with new technology. A number of the participants insisted that students needed a new basic tool kit for reasoning in new ways: how to understand and generate algorithms, how to appreciate the difference between computation and mathematics, how to mine and analyze large repositories of data, and how to employ and comprehend statistical data. We believe it is critical for students both to understand and to practice these different modes of thought. Once again, we favor an “embedded” approach to teaching such skills in a variety of courses and disciplines, and often with project-based learning. But we also believe that institutions need to be more mindful and purposeful about providing a more versatile tool kit of quantitative strategies in their general education and departmental curricula.

Bolster training for faculty/staff

Our students do not comprehend the science, engineering, and logical structures that animate our technology as deeply as experts in various disciplines may. Nevertheless, our students are more comfortable, familiar, intuitive, and adaptive in their deployment of a wide spectrum of technology. Institutions need to recognize that sufficient resources and support must be provided to faculty members and staff—those charged with the educational mission. Once again, we advocate a reactive approach—making readily available a variety of just-in-time, as-needed support mechanisms rather than trying to teach a set of prescribed skills in advance. Of course, on the administrative side, it may be necessary to train an entire cohort of employees on a new software package. But the key to success there, as everywhere, is to recognize how critical it is to follow-up with support resources to
reinforce that learning on demand. Faculty in particular can place a heavy obligation on the institution for individualized support, and even partnership, both for their research and for their pedagogy. Institutions must be committed to providing that support as needed.
Among the multitudinous documents and websites that the Teagle group examined in preparation for defining their task (see Appendix C for list of current websites), the 1999 report produced by the Computer Science and Telecommunications Board of the National Research Council stood out as a seminal effort to define the topic of technology fluency and address its most pressing questions. That report attempted to define fluency with information technology (abbreviated as FITness), to make the case for its critical importance in society at large and in education, and to delineate the central features that would constitute FITness.

Below are the key sections from the 1999 report, reprinted here in the body of the White Paper rather than in the Appendix because our work that follows is based closely on this text and relies on the reader’s familiarity of it. First, the report’s Executive Summary:

**Executive Summary**

Information technology is playing an increasingly important role in the work and personal lives of citizens. Computers, communications, digital information, software--the constituents of the information age--are everywhere.

Between those who search aggressively for opportunities to learn more about information technology and those who choose not to learn anything at all about information technology, there are many who recognize the potential value of information technology for their everyday lives and who realize that a better understanding of information technology will be helpful to them. This realization is based on several factors:

- Information technology has entered our lives over a relatively brief period of time with little warning and essentially no formal educational preparation for most people.
• Many who currently use information technology have only a limited understanding of the
tools they use and a (probably correct) belief that they are underutilizing them.
• Many citizens do not feel confident or in control when confronted by information
technology, and they would like to be more certain of themselves.
• There have been impressive claims for the potential benefits of information technology,
and many would like to realize those benefits.
• There is concern on the part of some citizens that changes implied by information
technology embody potential risks to social values, freedoms or economic interests,
etc., obligating them to become informed.

And, naturally, there is simple curiosity about how this powerful and pervasive technology
works.

These various motivations to learn more about information technology raise the general
question, What should everyone know about information technology in order to use it more
effectively now and in the future? Addressing that question is the subject of this report.

The answer to this question is complicated by the fact that information technology is
changing rapidly. The electronic computer is just over 50 years old, "PC," as in personal
computer, is less than 20 years old, and the World Wide Web has been known to the public
for less than 5 years. In the presence of rapid change, it is impossible to give a fixed, once-
and-for-all course that will remain current and effective.

Generally, "computer literacy" has acquired a "skills" connotation, implying competency with
a few of today's computer applications, such as word processing and e-mail. Literacy is too
modest a goal in the presence of rapid change, because it lacks the necessary "staying
power." As the technology changes by leaps and bounds, existing skills become antiquated
and there is no migration path to new skills. A better solution is for the individual to plan to
adapt to changes in the technology. This involves learning sufficient foundational material to
enable one to acquire new skills independently after one's formal education is complete.

This requirement of a deeper understanding than is implied by the rudimentary term
"computer literacy" motivated the committee to adopt "fluency" as a term connoting a higher
level of competency. People fluent with information technology (FIT persons) are able to express themselves creatively, to reformulate knowledge, and to synthesize new information. Fluency with information technology (i.e., what this report calls FITness) entails a process of lifelong learning in which individuals continually apply what they know to adapt to change and acquire more knowledge to be more effective at applying information technology to their work and personal lives.

Fluency with information technology requires three kinds of knowledge: contemporary skills, foundational concepts, and intellectual capabilities. These three kinds of knowledge prepare a person in different ways for FITness.

- Contemporary skills, the ability to use today's computer applications, enable people to apply information technology immediately. In the present labor market, skills are an essential component of job readiness. Most importantly, skills provide a store of practical experience on which to build new competence.
- Foundational concepts, the basic principles and ideas of computers, networks, and information, underpin the technology. Concepts explain the how and why of information technology, and they give insight into its opportunities and limitations. Concepts are the raw material for understanding new information technology as it evolves.
- Intellectual capabilities, the ability to apply information technology in complex and sustained situations, encapsulate higher-level thinking in the context of information technology. Capabilities empower people to manipulate the medium to their advantage and to handle unintended and unexpected problems when they arise. The intellectual capabilities foster more abstract thinking about information and its manipulation.

For specificity, the report enumerates the ten highest-priority items for each of the three types of knowledge. (Box ES.1 lists these ten items for each type of knowledge.) The skills, linked closely to today’s computer usage, will change over time, but the concepts and capabilities are timeless.

Concepts, capabilities, and skills—the three different types of knowledge of FITness—occupy separate dimensions, implying that a particular activity involving information technology will
involve elements of each type of knowledge. Learning the skills and concepts and developing the intellectual capabilities can be undertaken without reference to each other, but such an effort will not promote FITness to any significant degree. The three elements of FITness are co-equal, each reinforcing the others, and all are essential to FITness.

FITness is personal in the sense that individuals fluent with information technology evaluate, distinguish, learn, and use new information technology as appropriate to their own personal and professional activities. What is appropriate for an individual depends on the particular applications, activities, and opportunities for being FIT that are associated with the individual's area of interest or specialization.

FITness is also graduated and dynamic. It is graduated in the sense that FITness is characterized by different levels of sophistication (rather than a single fluent/not fluent judgment). And, it is dynamic in that FITness entails lifelong learning as information technology evolves.

In short, FITness should not be regarded as an end state that is independent of domain, but rather as something that develops over a lifetime in particular domains of interest and that has a different character and tone depending on which domains are involved. Accordingly, the pedagogic goal is to provide students with a sufficiently complete foundation of the three types of knowledge that they can "learn the rest of it" on their own as the need arises throughout life.

Because FITness is fundamentally integrative, calling upon an individual to coordinate information and skills with respect to multiple dimensions of a problem and to make overall judgments and decisions taking all such information into account, a project-based approach to developing FITness is most appropriate. Projects of appropriate scale and scope inherently involve multiple iterations, each of which provides an opportunity for an instructional checkpoint or intervention. The domain of a project can be tailored to an individual's interest (e.g., in the department of a student's major), thereby providing motivation for a person to expend the (non-trivial) effort to master the concepts and skills of FITness. In addition, a project of appropriate scope will be sufficiently complex that
intellectual integration is necessary to complete it. Note also that much of the infrastructure of existing skills-based computer or information technology literacy efforts (e.g., hardware, software, network connections, support staff) will be important elements of efforts to promote FITness.

Although the essentials of FITness are for the most part not dependent on sophisticated mathematics, and should therefore generally be accessible in some form to every citizen, any program or effort to make individuals more FIT must be customized to the target population. Because the committee was composed of college and university faculty, the committee chose to focus its implementational concerns on the four-year college or university graduate as one important starting point for the development of FITness across the citizenry. Further, the committee believes that successful implementation of FITness instruction will require serious rethinking of the college and university curriculum. It will not be sufficient for individual instructors to revisit their course content or approach. Rather, entire departments must examine the question of the extent to which their students will graduate FIT. Universities need to concern themselves with the FITness of students who cross discipline boundaries and with the extent to which each discipline is meeting the goals of universal FITness.

In summary, FIT individuals, those who know a starter set of information technology skills, who understand the basic concepts on which information technology is founded, and who have engaged in the higher-level thinking embodied in the intellectual capabilities, should use information technology confidently, should come to work ready to learn new business systems quickly and use them effectively, should be able to apply information technology to personally relevant problems, and should be able to adapt to the inevitable change as information technology evolves over their lifetime. To be FIT is to possess knowledge essential to using information technology now and in the future.
Second, the key chapter that lays out the “Tripartite Approach” and the details of the three essential elements of FITness, as understood in 1999.

The Intellectual Framework of Fluency with Information Technology

2.1 What is Fluency with Information Technology?

Fluency with information technology (abbreviated as FITness) goes beyond traditional notions of computer literacy. As noted in Chapter 1, literacy about information technology might call for a minimal level of familiarity with technological tools like word processors, e-mail, and Web browsers. By contrast, FITness requires that persons understand information technology broadly enough to be able to apply it productively at work and in their everyday lives, to recognize when information technology would assist or impede the achievement of a goal, and to continually adapt to the changes in and advancement of information technology. FITness therefore requires a deeper, more essential understanding and mastery of information technology for information processing, communication, and problem solving than does computer literacy as traditionally defined. (Box 2.1 addresses the difference between literacy and FITness in more specific terms.)

Note also that FITness as described in this chapter builds on many other fundamental competencies, such as textual literacy, logical reasoning, and knowledge of civics and society. Information technology is a medium that permits the expression of a vast array of information, ideas, concepts, and messages, and FITness is about effectively exploiting that expressive power. FITness enables a person to accomplish a variety of different tasks using information technology and to develop different ways of accomplishing a given task.

FITness comes in degrees and gradations and is tied to different purposes. FITness is thus not an "end state" that is independent of domain, but rather develops over a lifetime in particular domains of interest involving particular applications. Aspects of FITness can be developed by using spreadsheets for personal or professional budgeting, desktop publishing tools to create or edit documents or Web pages, search engines and database management tools for locating
information on the Web or in large databases, and design tools to create visualizations in various scientific and engineering disciplines.

The wide variety of contexts in which FITness is relevant is matched by the rapid pace at which information technology evolves. Most professionals today require constant upgrading of technological skills as new tools become useful in their work; they learn new word processing programs, new computer-assisted design environments, or new techniques for searching the World Wide Web. Different applications of information technology emerge rather frequently, both in areas with long traditions of using information and information technology and in areas that are not usually seen as being technology-intensive. Perhaps the major challenge for individuals embarking on the goal of lifelong FITness involves deciding when to learn a new tool, when to change to a new technology, when to devote energy to increasing technological competency, and when to allocate time to other professional activities.

The above comments suggest that FITness is personal, graduated, and dynamic. FITness is personal in the sense that individuals evaluate, distinguish, learn, and use new information technology as appropriate to their own sustained personal and professional activities. What is appropriate for an individual depends on the particular applications, activities, and opportunities for FITness that are associated with the individual's area of interest or specialization, and what is reasonable for a FIT lawyer or a historian to know and be able to do may well differ from what is required for a FIT scientist or engineer. FITness is graduated in the sense that it is characterized by different levels of sophistication (rather than a single FIT/not-FIT judgment), and it is dynamic in that it requires lifelong learning as information technology evolves.

Put differently, FITness should not be assessed according to whether a person "has/does not have" all ten capabilities, and is not a single "pass/fail judgment." People with different needs and interests and goals will have lesser or greater stakes in the various components of FITness—they will obviously have greater stakes in those components that are most directly linked to their own individual needs. Nevertheless, the committee believes that all of the elements discussed below are necessary for individuals to exploit effectively the power of information technology across even a relatively small range of interests and needs.
2.2 The Elements of FITness

FITness involves three types of knowledge. These types, described briefly below, interact to reinforce each other, leading to deeper understanding of information technology and its uses.

- **Intellectual capabilities.** The intellectual capabilities of FITness refer to one’s ability to apply information technology in complex and sustained situations and to understand the consequences of doing so. These capabilities transcend particular hardware or software applications. Indeed, the items listed as capabilities in Section 2.4 have general applicability to many domains other than information technology. But a great deal of research (and everyday experience as well) indicates that these capabilities do not easily transfer between problem domains, and in general, few individuals are equally adept with these capabilities in all domains. For this reason, these capabilities can be regarded as "life skills" that are formulated in the context of information technology.

- **Fundamental concepts.** Concepts refer to the foundations on which information technology is built. This is the "book learning" part of fluency, although it is highly doubtful that a decent understanding of the concepts described in Section 2.5 can be achieved strictly through the use of textbooks. The concepts are fundamental to information and computing and are enduring in the sense that new concepts may become important in the future as qualitatively new information technologies emerge, but the presented list of fundamental concepts will be augmented with rather than replaced by new concepts.

- **Contemporary skills.** Skills refer to the ability to use particular (and contemporary) hardware or software resources to accomplish information processing tasks. Skills embody the intent of the phrase "knowing how to use a computer" as that phrase is colloquially understood. Skills include (but are not limited to) the use of several common software applications. The "skills" component of FITness necessarily changes over time because the information technology products and services available to citizens continually change. The enumeration given in Section 2.6 is appropriate for today, but the list would have been different five years ago and will surely be different five years from now.
Section 2.3 discusses the relationship of capabilities, concepts, and skills, as well as the role of knowledge in particular domains.

Intellectual capabilities and fundamental concepts of information technology are instantiated in or relevant to a wide variety of contexts. Intellectual capabilities and skills relate to very practical matters, getting at the heart of what it means to function in a complex technology-oriented world. And all have the characteristic that the acquisition of information technology skills, the understanding of information technology concepts, and the development of intellectual capabilities are lifelong activities. Over a lifetime, an individual will acquire more skills and develop additional proficiency with those skills, understand information technology concepts in a richer and more textured manner, and enhance his or her intellectual capabilities through engagement in multiple domains.

The discussion below proposes a “top ten” in each classification. (The ten are not listed in any order of priority.) Experts will doubtless recognize omissions and the list could easily be extended. But it is easy to generate longer lists, and at some point, the length of a list exceeds need, practicality, and even feasibility. The committee believes that it is important to identify the items of highest significance among possible alternatives, and the ten items in each category represent the committee's collective judgment of the most important. It is the committee's hope that all who draw from, build on, critique, or modify these lists will also impose a limit of ten on themselves.

2.3 A Tripartite Approach to FITness

Capabilities, concepts, and skills—the three different types of knowledge basic to FITness—occupy separate dimensions, implying that a particular activity involving information technology will involve elements of each type of knowledge. Learning information technology skills and concepts and developing the intellectual capabilities can be undertaken without reference to each other, but such an effort will not promote FITness to any significant degree. The three elements of FITness are co-equal, each reinforcing the others, and all are essential to FITness.²

- Study that emphasizes skills without fundamental concepts and intellectual capabilities meets some needs for utility in the short term. But although these skills enable one to perform basic tasks with a word processor (for example), they may not help much in countering the
frustration felt when the computer freezes, the printer cannot be accessed, or the paragraphs mysteriously develop new fonts. Similar frustration is often experienced by an individual learning a new word-processor. The fundamental concepts underlying information technology are the basis for a mental model of how a specific application is (or is not) working, a model that enables reflective thought about what might be done to fix a problem or how a new application might work. The capabilities of FITness enable a person to deal with unexpected consequences and make appropriate decisions about learning new features or new software, and they are necessary for one to engage in any kind of sustained effort using information technology.

- Study of information technology concepts in isolation from skills or capabilities is reminiscent of computer science education in the days before computers became abundant. The concepts represent abstract information about deep and interesting phenomena. They are worthy of study for their inherent interest, like studying sub-atomic particles and the structure of matter. But taught in the context of skills and capabilities, concepts also become the foundation on which one codifies one’s experience, abstracts to new situations, and reasons about information technology. As information technology changes, concepts provide the basis for adapting to the change, inasmuch as the new systems adhere to the same principles the old systems did. Further, concepts provide the raw material needed to engage in capability-based action such as engaging in sustained reasoning and managing complexity.

- Study that emphasizes capabilities at the expense of concepts and skills will lack the essential connection to information technology. Although the intellectual capabilities are quite general, their development in the context of FITness requires a substantive connection to information technology that is provided by exposure to the concepts and skills. For example, to learn to "debug" a program or test an application, students need to understand the concepts implemented in the artifact. To implement their designs and work with others they need communication and search skills.

FITness integrates skills, concepts, and capabilities into an effective understanding of information technology, enabling citizens to use information technology to solve personally relevant problems and apply their knowledge of information technology to new situations. This integration is an
essential element for individuals to learn over a lifetime. Thus, a pedagogical approach that balances the treatment of these three elements is essential—this is the subject of Chapter 4.

2.4 Intellectual Capabilities for FITness

1. Engage in sustained reasoning.
2. Manage complexity.
3. Test a solution.
4. Manage problems in faulty solutions.
5. Organize and navigate information structures and evaluate information.
6. Collaborate.
7. Communicate to other audiences.
8. Expect the unexpected.
10. Think about information technology abstractly.

2.5 Information Technology Concepts

1. Computers

Key aspects of a stored-program computer, including:

- The program as a sequence of steps,
- The process of program interpretation,
- The memory as a repository for program and data (including notions of memory hierarchy and associated ideas of permanence/volatility), and
- Overall organization, including relationship to peripheral devices (e.g., I/O devices).

2. Information systems

3. Networks

4. Digital representation of information

5. Information organization

6. Modeling and abstraction
2.6 Information Technology Skills

Today's set of ten essential skills includes:

1. Setting up a personal computer
2. Using basic operating system features
3. Using a word processor to create a text document
4. Using a graphics and/or artwork package to create illustrations, slides, or other image-based expressions of ideas
5. Connecting a computer to a network
6. Using the Internet to find information and resources
7. Using a computer to communicate with others
8. Using a spreadsheet to model simple processes or financial tables
9. Using a database system to set up and access useful information
10. Using instructional materials to learn how to use new applications or features

2.7 FITness in Perspective

The intellectual content of FITness is rich and deep. But the depth and richness of this content are determined by the nature of information technology. Although different individuals need different degrees of familiarity with the different elements of FITness, a good understanding of and facility with all of the skills, concepts, and capabilities of FITness are necessary for individuals to exploit the full power of information technology across a range of different applications.

Nevertheless, such depth and richness raise the question of the extent to which it is reasonable to expect that the content of FITness is accessible to a wide range of the citizenry. For perspective on this question, it is useful to consider the National Council of Teachers of Mathematics' (NCTM) standards for mathematics education and the National Research Council's
standards for science education. As described in Appendix B, such organizations focus on the 
mathematical and scientific education of all students, rather than a special few with previously 
demonstrated aptitude for mathematics or science. The organizations that produced these 
standards for mathematics and science education make the case that the intellectual content 
articulated in the standards is rich, deep, and most importantly not "dumbed down." These 
organizations believe that learning about science and mathematics is valuable not just for future 
scientists and mathematicians, but also for a very wide range of the citizenry.

The essentials of FITness are not for the most part dependent on knowledge of sophisticated 
mathematics. Indeed, the capabilities and concepts, though not the skills, are intellectually 
accessible even without computers per se. For example, the concept of an algorithm can be 
expressed and conveyed in an entirely qualitative and non-mathematical manner even to a 4th 
grader by discussing the rules of a game or following a recipe in the kitchen. Thus, the committee 
believes that the intellectual content of FITness is no less accessible to citizens than the 
mathematics and science contained within the NCTM and NRC standards.

A second issue is the following: by design, FITness is a body of knowledge and understanding 
that enables individuals to use information technology effectively in a variety of different contexts. 
But does being FIT mean that one will never need to rely on an information technology expert? 
Put differently, does an individual's consultation of an information technology expert imply a lack 
of FITness for that individual?

There is certainly some level of FITness at which an individual will not need to rely on an expert 
to fix an information technology problem or to exploit a new opportunity offered by information 
technology. But even someone who is FIT enough to not have to rely on an expert may find it 
advantageous to do so anyway. For example, a highly FIT individual may simply decide that it is 
not worth his or her time to fix a problem, even if he or she could do so. Furthermore, even if an 
individual with more basic levels of FITness may still need to consult with an information 
technology expert to solve a technology problem or to describe a technology solution, that basic 
understanding and knowledge will help him or her to interact constructively with the expert (e.g., 
to recognize that a problem is indeed solvable; to explain the problem or solution requirements 
more precisely; or to understand, implement, or dispute an approach that the expert proposes).
IV. Updating *Being Fluent* with Information Technology

The Teagle group quickly targeted the heart of the *Being Fluent* document, called the “Tripartite Approach to FITness”: lists of skills, concepts and capabilities that the report’s authors considered the essential elements of FITness. We took little issue, and saw little reason to try to improve upon, the basic case made by the authors or the general definitions they proposed. For example, the 1999 report answered the contested question of term—“fluency” or “literacy”?—in the same way as the original proposal for the Teagle Foundation grant does: in favor of “fluency.” Here is what the report says:

> While no term is perfect, the notion of *fluency* captures best for the committee connotations of the ability to reformulate knowledge, to express oneself creatively and appropriately, and to produce and generate information (rather than simply to comprehend it). For this reason, the committee chose “fluency with information technology,” or FITness, as a label for the robust understanding of what is needed to use information technology effectively across a broad range of applications. (p. 14)

However, when we hit a sentence in the report’s Executive Summary such as—

> The electronic computer is just over 50 years old, "PC," as in personal computer, is less than 20 years old, and the World Wide Web has been known to the public for less than 5 years. In the presence of rapid change, it is impossible to give a fixed, once-and-for-all course that will remain current and effective. (p. 2)

—we knew it was time to revisit these questions. To our knowledge, no revision or update of this report, now 8 years old and begun more than a decade ago, has been attempted. Ironically, the main point of the sentence above—that things are changing so quickly in the world of information technology that there is no single way to “teach” fluency—is precisely the reason why the document called out for reconsideration. Now, some eight years later, our group arrived at the same conclusion.
and acknowledge that our own update will be ripe for revision itself, and probably sooner than eight years from now.

At our first meeting in Lexington, the group recognized the validity of the “Tripartite Approach”—labeled as Intellectual Capabilities, Fundamental Concepts, and Contemporary Skills. There was considerable discussion of the report’s claim that the “intellectual capabilities” necessary to attain technology fluency were in some way special, although not unique, to this new area of knowledge. (That philosophical argument is reflected in the more theoretical approach taken by the “Intellectual Capacities” group in their report.) However, we decided the framework established by the 1999 report was thoughtful and thorough; it was unnecessary labor to try to re-invent that particular wheel. Instead, we would modernize it.

After our own brainstorming session about the meanings and importance of technology fluency, however, we quickly focused on one major shortcoming and omission of the 1999 report—an understandable one given the relatively early date of its publication. That is the lack of attention to the impact of this new pervasive technology on society and individual lives—a huge set of concerns that we chose to label “Society, Aesthetics, Ethics, and Values.” The 1999 report did not totally ignore these issues, but they are relegated to a curt discussion in Box 1.1, on p. 12 of the report, called “Possible Social Effects of Information Technology” and included this list of five effects: freedom, world connectivity, loss of remoteness, alienation, and predominance of English.

Therefore, our group subdivided into four working groups—Intellectual Capabilities, Fundamental Concepts, Contemporary Skills, and Society, Aesthetics, Ethics, and Values. Working in those four groups comprised the bulk of our efforts at our second meeting at Drew University. Before breaking
into groups, we agreed that each group should keep in mind a set of key questions as we reconsidered the lists from the 1999 document.

- In what ways are these skills/knowledge teachable or learnable?
- Are they distinct one from another? How?
- How are they different now than they were in 1999?
- What is the best way to “deliver” them in a higher education setting?

What follows are the reports of the four working groups—the heart of this collective project. The individual reports, drafted by a representative from each group, have been only lightly edited because each group developed its own approach and rationale for its work. The key questions above are answered within the text of each working group’s report. However, the groups’ answers to final question above, concerning how best to “deliver” the material in each category, are summarized first. These answers, arrived at independently in each working group, coalesce around several themes which helped the group as a whole arrive at the “Key Findings” that appear earlier in this White Paper. Those Key Findings represent our major recommendations for implementation at the higher education level.

Intellectual Capabilities….are best delivered by means of:

- Project-based assignments in courses or entire project-based special courses
- Not in any single course, but diffused throughout curriculum
- Better training for faculty—through incentives for professional development

Fundamental Concepts….are best delivered by means of:
Project-based assignments in courses

Taught in “stealth” ways through a variety of courses as needed, not in a single course

If as a single course, one that meets general education requirements

Orientation sessions for new students to the computing environment at the institution

Contemporary Skills…are best delivered by means of:

- Project-based assignments that require learning a variety of key skills
- Support systems on campus (on-line tutorials, peer tutors, help desk) on an “as-needed” basis

Society, Aesthetics, Ethics, and Values….are best delivered by means of:

- A selection of elective courses, ideally interdisciplinary
- Content diffused in courses throughout the curriculum in many disciplines, as appropriate
- Project-based assignments that apply ethical questions to complex issues
- Inclusion of some IT issues in the syllabus if the institution has something like an “Ethics” requirement
- Through orientation and other support structures, as well as individual syllabi, to address issues such as the ethical use of web, plagiarism, etc
IV. A. The Intellectual Capabilities group

Summary from *Being Fluent*

In addition to the specific computing concepts and skills deployed in understanding and using information technology, *Being Fluent* identifies a set of “intellectual capabilities” that are implicated. “The intellectual capabilities of FITness refer to one's ability to apply information technology in complex and sustained situations and to understand the consequences of doing so.” (p. 17) The authors go on to list ten.

1. *Engage in sustained reasoning.*
2. *Manage complexity.*
3. *Test a solution.*
5. *Organize and navigate information structures and evaluate information.*
7. *Communicate to other audiences.*
8. *Expect the unexpected.*
10. *Think about information technology abstractly.*

With the exception of the last two, these capabilities are not peculiar to computing or the use of information technology. One can surely engage in sustained reasoning (item 1) in diverse domains—consider developing a proof of a mathematical theorem or constructing a valid test of an empirical hypothesis or evaluating various explanations of an historical event or analyzing a poem—without engaging with IT. The same point could be made with most of the other items on the list. But because people who exhibit a capability in one domain are often not able to do so in another
domain, it is important to attend to these capabilities with specific reference to how they are exhibited by someone who is fluent with IT. Moreover, if the goal is fluency, the intellectual capabilities must be cultivated along with computing skills and an understanding of computing concepts. Because of the rapidity with which IT changes, developing skills without concepts and intellectual capabilities at best serves only short-term goals. An emphasis on concepts without intellectual capabilities and skills confines the focus quite narrowly to the abstract concerns of computer science and does not show how computing enables one to manage information in virtually all domains of one’s life. “The three elements of FITness are co-equal, each reinforcing the others, and all are essential to FITness.” (p. 19)

**General observations**

*Intellectual capabilities as an element of FITness*

The working group briefly discussed the place of intellectual capabilities within *Being Fluent’s* tripartite conception of fluency. We agreed that it made sense to include intellectual capabilities as a separate component of fluency, which should be integrated with the other two components in efforts to teach information technology at the collegiate level. Courses or programs aimed at teaching IT skills in isolation from a broader concern with students’ intellectual development would not have lasting educational benefits and would not be the kind of educational experience for which our institutions would be inclined to give academic credit. Courses or programs aimed at teaching only concepts (or concepts and skills) without connecting these with a student’s broader, emerging intellectual capabilities would appeal only to students with an interest in computers per se. Indeed, for them, it is hard to imagine how one could possibly divorce concepts and skills from the broader capabilities. A program aimed at promoting fluency among college students needs to make clear to them that being fluent is not just for geeks or those who happen to feel comfortable around
computers but for all who want to realize the broader goals of a liberal arts education—facility with critical thinking; with gathering, analyzing and interpreting information; with communicating ideas and information; etc.

**Intellectual capabilities and the liberal arts**

This element of FIT'ness is key to the argument that FIT'ness has a place among the goals of a liberal arts education in the 21st century. Intellectual capabilities are habits of mind commonly understood to be characteristic of educated persons, and cultivating them has long been recognized as an important goal of a liberal education. Information technology presents an ideal opportunity for students to develop these capabilities, which may even take on a distinctive form when exercised in connection with the use of information technology. Furthermore, because digital information so pervades the world in which we live, facility with the most powerful techniques for accessing, manipulating, analyzing, and presenting information is essential to understanding our world and to intellectual engagement with it.

An example of one such intellectual capability, item three from the list of ten identified in *Being Fluent*, is “testing a solution.” Educators since at least Socrates have tried to impress upon their students the importance of testing what purports to be the solution to a problem. (For a charming example, see the discussion of the problem of doubling the area of a square in Plato’s *Meno.*) Socrates and a whole line of rationalists who followed him emphasized a deductive mode of testing designed to tease out the coherence of a proposition with other accepted truths or to ascertain its soundness as derived logically from first principles. Today, we emphasize as well, or stress even more, inductive, empirical modes of testing. In explicating what is distinctive about experimental science, the notion of a hypothesis—a general statement proposed as true that must then be tested through controlled observations—is central.
Teaching computing concepts and skills provides an excellent vehicle for developing a student’s capacity for both deductive and inductive reasoning. With respect to deductive reasoning, computers are, after all, physical embodiments par excellence of a formal deductive system. By learning about their formal characteristics, one begins to trust that they function (usually) exactly as they are designed to function. If a desired outcome of a certain operation does not occur, it may be because one of the necessary preconditions has not been fulfilled. This is exactly the same as discovering that one of the assumptions of one’s argument is false. Or the outcome may not occur because there is a bug in the program. Discovering that is just like discovering that there is a formal fallacy in one’s argument.

But computing is not just about deductive modes of reasoning. A good deal of what one can understand about how a computer functions or a program works does not rise to the level of understanding how particular outcomes follow logically from first principles. In addition to being a wonderfully-wrought logistical system, a computer is a tool for getting various jobs done, and one can learn quite a bit about whether or how a computer can complete a particular task just by experimentation. For instance, a useful device in the popular spreadsheet application Excel is a pivot table. With a few clicks one can analyze data in a list and summarize them in tabular form based on a selection of certain columns. One does not have to know how the program performs this wonderful feat. By experimenting with the selection and placement of various columns, one can figure how to work with the data to get the desired outcome. In fact, most of the competent layperson’s knowledge of how to use a computer is derived in this trial-and-error, empirical manner, and not through a rigorous understanding of underlying logical and mathematical principles governing the behavior of a computer.

Many faculty in a liberal arts college would bristle at the idea that students should receive academic credit for learning technical skills. Very few if any would argue that learning concepts of computer
science belongs in the core of a liberal arts education, even if most would allow computer science as one among many disciplines through which students could fulfill a requirement in the mathematical or physical sciences. A richer conception of FITness, however, that includes intellectual capabilities as well as skills and concepts does begin to look like other elements of a liberal arts education. Like the ability to express oneself effectively through writing or the ability to use a foreign language, FITness has become indispensable to the processes though which scholars and researchers work with the materials of their disciplines to critically engage with and understand the world.

The list of capabilities

The group considered the list of ten specific capabilities discussed in *Being Fluent*. The list seems somewhat idiosyncratic, and the items together do not fit any pattern suggesting that the list was comprehensive. No one, however, had any fundamental objections to the individual items, aside from finding that one of the items—managing complexity—to be a bit vague.

One question the list invites is whether the items represent the intellectual capabilities involved in learning to use computers, those involved in actually using computers with some degree of mastery, or those involved in developing computing applications and technologies. The authors’ explication of the items in the list suggests that they had the latter in mind. That is, they tended to assume that it is through projects of application development that computing engages the intellect in ways that are of most interest to those concerned with promoting fluency. Valuable as such projects can be in developing intellectual capabilities that we recognize as the concern of a liberal arts education, they are not the only path to IT literacy. Nor are they likely to become a standard component of a liberal arts education.

It should be possible to show that projects and assignments undertaken in learning to use a computer to investigate something else are equally useful for developing these same intellectual
capabilities (engaging in sustained reasoning, managing complexity, testing a solution, and the rest). As such, the computer is not the object of study, or at least not the primary object of study. The object of study might be a classical text or a biological molecule or immigration patterns. The computer comes into play because it offers a powerful means of analysis, modeling, problem-solving, or presentation that opens up new modes of inquiry and makes new knowledge possible. In pursuing such projects through the use of IT, it is true, students will encounter problems that are not about the primary object of study but are about computing. In solving these problems, they develop stronger computing skills and perhaps a deeper understanding of computing concepts. And they exercise basic intellectual capabilities both through their engagement with the primary object of study and in working through certain issues of computing along the way. IT fluency will find its most profound place in the liberal arts curriculum when it is not just the business of the computer science department but is rather emphasized in the specific contexts of disciplines across the university.

Are there other items not mentioned by Being Fluent?

The sub-group wondered whether there were other intellectual capabilities that should be added to those proposed in Being Fluent. Some items we discussed were synonymous with some on the Being Fluent list but with a different emphasis that perhaps reflected less of a preoccupation with computing as application development. These included: critical thinking, troubleshooting, hypothesis formation and experimentation, sensitivity to carelessness in the use of language (computers are unforgiving). Other items we considered reflected changes in the nature of computing since Being Fluent was published. We present these somewhat tentatively in the form of a number of questions.
• Does contemporary computing make special demands on users to develop the capacity for multi-tasking?

• What capabilities come into play when information is presented, as the web has made commonplace, in hypertextual form, that is, when reading is typically not done in linear fashion?

• What critical capacities are required when publication no longer requires approval by a publisher based on scholarly or commercial merits, when virtually anyone can publish virtually anything?

• In what ways has contemporary computing contributed to our, and especially to our students’, becoming more drawn to visual and aural modes of presentation and perhaps less engaged by the purely textual? That is, what forms do critical thinking, sustained reasoning, testing solutions, or problem-solving take when visual and aural modes of presentation are emphasized?

One caution concerning the Being Fluent list of intellectual capabilities can be expressed in terms of Marc Prensky’s distinction between digital immigrants and digital natives. Most of our students are digital natives: they have grown up entirely in the digital age. (See www.marcprensky.com/writing/). For them, the intellectual challenges, and therefore the opportunities for intellectual growth, posed by computing are likely to be different from those once faced by today’s college educators, who are almost universally of the generation of “digital immigrants.” The shift from immigrant to native implies at the very least that some, if not all, of the items we have identified need to be explicated in new ways. Critical thinking about an image makes intellectual demands for which one schooled in critical reading of texts may be unprepared. This difference is such that the shift may entail distinctive intellectual capabilities in addition to the ones we have identified. It is clear that our students have a certain familiarity with computing and
digital media, which will always be somewhat like a second language for most of us. And so we need
to listen to them, especially to most fluent among them, to learn in what ways computing engages
and empowers them intellectually. But we also need to consider and to help our students consider
the intellectual consequences of an uncritical absorption with IT, to which they are especially
susceptible.

Revised list of Intellectual Capabilities

1. Engage in sustained reasoning.
2. Use language with logical precision.
   (“Manage complexity” is dropped because too vague.)
3. Formulate hypotheses, devise appropriate experiments, test possible solutions. (expanded
   from “test a solution”)
4. Use effective troubleshooting strategies
   Revises “Manage problems in faulty solutions.”
5. Organize and navigate information structures and evaluate information.
6. Collaborate.
7. Communicate to other audiences.
8. Expect the unexpected.
10. Think about information technology abstractly.
11. Manage multiple tasks simultaneously.
12. Employ visual or aural media to enhance verbal presentation of information and ideas.
Description of the category from *Being Fluent*:

Fundamental concepts. Concepts refer to the foundations on which information technology is built. This is the “book learning” part of fluency, although it is highly doubtful that a decent understanding of the concepts described in Section 2.5 can be achieved strictly through the use of textbooks. The concepts are fundamental to information and computing and are enduring in the sense that new concepts may become important in the future as qualitatively new information technologies emerge, but the presented list of fundamental concepts will be augmented with rather than replaced by new concepts. (p. 18)

The authors of *Being Fluent* itemize these fundamental concepts as follows:

1. Computers
2. Information systems
3. Networks
4. Digital representation of information
5. Information organization
6. Modeling and abstraction
7. Algorithmic thinking and programming
8. Universality
9. Limitations of information technology
10. Societal impact of information and information technology
In reviewing these concepts and considering what has changed since the report was issued, we focused on 3 questions:

1) Is the component still validly a part of what we regard as a “fundamental concepts” underlying IT?

2) Is the component teachable?

3) What has changed about the component since the issuance of the NRC report?

Our discussions centered on the first and third questions: we felt that the extent to which any of these concepts is “teachable” depends in large measure on the specific approaches to IT Fluency that are adopted on a campus, and could not be profitably addressed in this context.

Components:

1) Computers:

Described in *Being Fluent* as: “Key aspects of a stored-program computer, including:

- The program as a sequence of steps,
- The process of program interpretation,
- The memory as a repository for program and data (including notions of memory hierarchy and associated ideas of permanence/volatility, and
- Overall organization, including relationship to peripheral devices (e.g., I/O devices).” (p. 29)

We agree that understanding the concepts underlying the way computers operate is fundamental.

Our list would include:

- The program as a sequence of steps.
• The concept of a stored “instruction set”, with limited capabilities that can nonetheless be harnessed to “simulate” or “model” complex processes.

• The memory as a repository for program and data (including notions of memory hierarchy and associated ideas of permanence/volatility).

• The concept of the “register” as a local working buffer (and implications of its finite size).

• The concept of a Turing machine, and the “universal” computer.

• The concept of an algorithm (relates to first point) … a formula for systematically decomposing and solving a problem.

• The concepts of “interpretation” versus “compilation”, and the difference between “scripting” and “programming” languages.

• The concept of “computability” (can a problem be decomposed into an algorithm and, if so, how does such an algorithm scale?).

We did not think that “overall organization” was fundamental.

2) Information Systems:

Described in Being Fluent as: “The general structural features of an information system, including, among others, the hardware and software components, people and processes, interfaces (both technology interfaces and human-computer interfaces), databases, transactions, consistency, availability, persistent storage, archiving, audit trails, security and privacy and their technological underpinnings.” (p. 29)

We felt this should be dropped from the list of “fundamental concepts”. Even “fundamental” organizational principles like client-server change rapidly. Maybe this might be part of a “current skills” curriculum
3) Networks:

Described in *Being Fluent* as: “Key attributes and aspects of information networks, including their physical structure (messages, packets, switching, routing, addressing, congestion, local area networks (LANs), wide area networks (WANs), bandwidth, latency, point-to-point communication, multicast, broadcast, Ethernet, mobility), and logical structure (client/server, interfaces, layered protocols, standards, network services).” (p. 29)

We agree that the concepts underlying networking are fundamental, and the NRC description of the elements of networking are still valid and appropriate. We would add IP, along with Ethernet, to the list of items making up some fundamental elements of IT networking.

4) Digital Representation of Information:

Described in *Being Fluent* as: “The general concept of information encoding in binary form. Different information encodings: ASCII, digital sound, images, and video/movies. Topics such as precision, conversion and interoperability (e.g., of file formats), resolution, fidelity, transformation, compression, and encryption are related, as is standardization of representations to support communication.” (p. 30)

We agree that digitization is a fundamental concept underlying IT, and the NRC description covers much of what needs to be known about it. Some specific items that we would add to the description include the concept of standardization (the process of agreeing on standards, and how standards work), the notion of “word size” as it relates to precision and representation of, particularly, numeric information, and the issues underlying preservation of digital information.
5) Information Organization:

Described in Being Fluent as: “The general concepts of information organization, including forms, structure, classification and indexing, searching and retrieving, assessing information quality, authoring and presentation, and citation. Search engines for text, images, video, audio.” (p. 30)

We felt that this topic did not belong under “fundamental concepts”, but rather related to information fluency in a context much broader than IT. Classification and indexing and searching and retrieving predate IT, and most of the “fundamental concepts” involved are not at all specific to IT systems. However, there is certainly a piece of this that would need to be addressed in the “skills” area of IT Fluency.

6) Modeling and Abstraction:

Described in Being Fluent as: “The general methods and techniques for representing real-world phenomena as computer models, first in appropriate forms such as systems of equations, graphs, and relationships, and then in appropriate programming objects such as arrays or lists or procedures. Topics include continuous and discrete models, discrete time, events, randomization, and convergence, as well as the use of abstraction to hide irrelevant detail.” (pp. 30-31)

As with Information Organization, we felt that much of this was not unique to IT (at least not at the level of a “fundamental concept”) but should be treated by more skills-focused IT training. In particular, we felt that IT systems might make a unique class of models implementable, in particular, various kinds of games. (See component #8 of the Contemporary Skills group.)

7) Algorithmic thinking and programming:

Described in Being Fluent as: “The general concepts of algorithmic thinking, including functional decomposition, repetition (iteration and/or recursion), basic data organizations (record, array, list),
generalization and parameterization, algorithm vs. program, top-down design, and refinement. Note also that some types of algorithmic thinking do not necessarily require the use or understanding of sophisticated mathematics. The role of programming, which is a specific instantiation of algorithmic thinking, is discussed in Chapter 3” (p. 31).

We agree that nothing is more fundamental to IT than the concept of the algorithm and the expression of the algorithm as a discrete set of steps in a computer language. However, we would put this under the “computers” category described above, as this is fundamentally what a “computer” is and does. The definition should also include mention of finite state automata and the distinction between and equation and an algorithm (and the difference between a computational versus an analytical approach to solving a problem).

8) Universality:

Described in *Being Fluent* as: “The "universality of computers" is one of the fundamental facts of information technology discovered by computing pioneers A.M. Turing and Alonzo Church in the 1930s, before practical computers were created. Shorn of its theoretical formalism and expressed informally, universality says that any computational task can be performed by any computer. The statement has several implications:

- No computational task is so complex that it cannot be decomposed into instructions suitable for the most basic computer.
- The instruction repertoire of a computer is largely unimportant in terms of giving it power since any missing instruction types can be programmed using the instructions the machine does have.
- Computers differ by how quickly they solve a problem, not whether they can solve the problem.
• Programs, which direct the instruction-following components of a computer to realize a computation, are the key.

Universality distinguishes computers from other types of machines (Box 2.2).” (pp. 31-32)

We agree that this, along with the concept of the algorithm, is absolutely fundamental, and, as with the algorithm, we would include it as part of an expanded definition of the concept of a “computer” (item 1 above). We think that “Universality” is a bad term for this aspect of the computer, but that the definition is very good.

9) Limitations of Information Technology:

Described in Being Fluent as: “The general notions of complexity, growth rates, scale, tractability, decidability, and state explosion combine to express some of the limitations of information technology. Tangible connections should be made to applications, such as text search, sorting, scheduling, and debugging.” (p. 32)

We agree that these are important issues, but think that they should be incorporated, as appropriate, into each of the foregoing items. “Limitations” by itself is not a concept, but rather is a component part of the other concepts (e.g., the limitations of algorithms, the limitations of digital representations of information).

We also think that some elements of the description of limitations are not only not fundamental, but may indeed be fundamentally wrong! For example: “Computers possess no intuition, creativity, imagination, or magic.” (p. 32) Who knows whether or not this will be true 100 years (or even 20 years) from now? Some people (including one in the group) believes that people are fundamentally nothing more than very, very complex computers.
10) Societal impact of information technology:

Described in *Being Fluent as*: “The technical basis for social concerns about privacy, intellectual property, ownership, security, weak/strong encryption, inferences about personal characteristics based on electronic behavior such as monitoring Web sites visited, "netiquette," "spamming," and free speech in the Internet environment.” (pp. 33-34)

We did not address this, as we have elevated it to an entirely separate category of IT Fluency (see report of the Society, Aesthetics, Ethics, and Values group).
IV. C. The Contemporary Skills group

The third main grouping of components in Being Fluent is a list of ten items is sometimes called Contemporary Skills and sometimes Information Technology Skills. Here is the short description of the category from Being Fluent, with a critical passage, acknowledging the inevitability of change over time, in bold italics. Perhaps more for this category than for Intellectual Capabilities or Fundamental Concepts, the authors of the 1999 report recognize how their work would evolve even in the brief span of five years.

*Contemporary skills.* Skills refer to the ability to use particular (and contemporary) hardware or software resources to accomplish information processing tasks. Skills embody the intent of the phrase "knowing how to use a computer" as that phrase is colloquially understood. Skills include (but are not limited to) the use of several common software applications. The "skills" component of FITness necessarily changes over time because the information technology products and services available to citizens continually change. The enumeration given in Section 2.6 is appropriate for today, but the list would have been different five years ago and will surely be different five years from now. (p. 18)

Clearly, the authors of the 1999 report appreciate that the list of “skills” they had compiled was peculiar to a particular moment in the evolution of technology. Seven years, in the technology revolution, is virtually an epoch. In turn, we acknowledge that this list is well-conceived, forward-looking and comprehensive. No skill listed in 1999 is obsolete in 2006. Nevertheless, the list has its limitations, most obviously that it is tied to particular software package functions such as word processing, spreadsheets, databases, graphics, etc. In some cases, we propose a reformulation,
broadening, and re-grouping of these items; in other cases, we add new items—such as computer security—that have, over the years, gained prominence in terms of the set of basic skills that competent computer users require.

Here is the 1999 list of “contemporary skills”:

Today's set of ten essential skills includes:

1. Setting up a personal computer
2. Using basic operating system features
3. Using a word processor to create a text document
4. Using a graphics and/or artwork package to create illustrations, slides, or other image-based expressions of ideas
5. Connecting a computer to a network
6. Using the Internet to find information and resources
7. Using a computer to communicate with others
8. Using a spreadsheet to model simple processes or financial tables
9. Using a database system to set up and access useful information
10. Using instructional materials to learn how to use new applications or features

As the working group considered this list, some themes emerged that helped organize our ideas:

First, given the rapidity of change and innovation in both basic technology and commercial products (both hard and soft), the core skill is “to know how to learn other, new skills.” In other words, adaptability is crucial—and in that way this core skill overlaps with the work of other working groups on both “Fundamental Concepts” and “Intellectual Capabilities.” The ability to adapt to a new software upgrade or a new piece of hardware, without dependence on experts, is based on the ability to understand and recognize underlying principles and patterns—and so requires a combination of intellectual capacity and basic conceptual knowledge. In that way, the products of
our four working groups are not distinct or independent, but rather intimately connected and interdependent—a point made strongly in the 1999 report.

Second, in a way that was not fully available or obvious in 1999, we did our thinking in terms of “networks” both of things and people. As computer networks, both local and global, have become more robust, more far-reaching, and more versatile in terms of equipment (Blackberries, cell phones, iPods, etc), the very nature of using a computer has shifted dramatically. Fluent users of technology now require both a basic understanding of how to network their device with other devices, and how to connect in a variety of ways to other people—though new on-line communities, websites, blogs, etc. This element of fluency is no longer technical only; it is as much about the protocols and etiquettes of network-enhanced human interactions.

Finally, as we considered the value of the list of skills from the 1999 document, we arrived at an easy way of categorizing for ourselves the main functions of computing and information technology. They are 1) to find information, 2) to store information usefully, and 3) to generate information. Those basic rubrics helped us to organize our revised list of contemporary skills central to technology fluency today. In some cases, we have re-named and re-conceived skills on the 1999 list; in others, we propose new skills. We have used bullet points to highlight the key points of each of the nine skills.

1. Versatile Use of Computers (Formerly “Set up personal computer”)

As computers and other devices have become more diverse and versatile, so must users. The emphasis here is on the a basic level of readiness and adaptability to manage rapid technological change.
• How to be a “smart consumer” of digital technology—how to evaluate needs, capabilities, prices (not just of computers, but of cameras, etc)

• How to adapt and modify computers to take advantage of current and emerging technologies and applications (both hardware upgrades or swaps and software downloads)

• How to interconnect computers with other electronic devices—such as cameras, phones, ipods, wireless networks, other peripherals

2. Mastering major functions and tools of computers (Formerly “Using basic operating system”)

As the operating systems of computers have become more transparent (at least on a basic functional level), this skill can be reworded.

• How to manage the basic functions of networking, storing information, various hardware and software tools and applications, system checks, basic troubleshooting

• How to use and produce graphics, video, and music on the computer or other devices

• How to adapt current understandings to new developments in hardware, software, and networking

3. Understanding issues and methods of security

With the network explosion has come a distressing new threat to the security of electronic data and transmissions—from spam, to identity theft, to exposure of sensitive data. Users must have a basic understanding of such threats and how to protect against them.

• How to maintain the health of a computer and its information

• How to protect data and identity

• How to protect from viruses, worms, etc.
4. How to “find information”

- How to locate and collect information from the full variety of sources: public internet, search engines, wikis, reliable websites, vetted academic resources, and statistical databases
- How to evaluate the accuracy, validity, appropriateness, and bias of such sources and information
- How to credit properly the sources of electronic information in one’s own work

5. How to “store information”

- How to use digital systems to archive and organize information and data in a retrievable, logical format. Examples include: how to organize Word folders and files, how to store and manipulate data in a spreadsheet or database, how to store photos or music, and how to organize calendars and address books.

6. How to “generate information”

- How to organize, format, and present information in a variety of forms and formats
- How to use word processing software, how to construct a webpage, how to use presentation software, how to construct spreadsheets and graphics

7. How to network

- How to fully utilize network resources where and when appropriate—set up and troubleshoot modest local networks
- How to utilize full range of peripherals and shared communication and storage resources
• How to be a “responsible network citizen” to protect interests and welfare of other people and equipment

• How to connect and communicate with other people via email and other technologies, how to establish virtual communities (from an email list, to a group doing a course project, to Facebook or MySpace)

8. How to use virtual environments for learning

• How to manipulate and learn from simulations and games in order to learn real-world skills (e.g., chemistry or physics simulations, how to fly a plane, how to practice a surgical technique)

9. How to get help

• How to seek and receive appropriate initial and continuing training

• How to locate and use more immediate sources of assistance (in software, online, in person)

• How to do basic maintenance, diagnosis and trouble shooting

Perhaps the most novel modification is the eighth skill: How to use virtual environments for learning. The exponential increase in computing power and speed has resulted in astounding new capabilities for graphics, modeling, games, and simulations. Users must become familiar, or at least comfortable, with these new tools and diversions, and should develop the adaptive ability to learn new programs and games based on their experience with the old. In fact, here our work clearly overlaps with the *Intellectual Capabilities* group charged with thinking through how, if at all, human cognitive (and sometimes physical) abilities and modes of thought are new and different as a result of human-computer interaction.
The question of the impact of information technology, and its rapid pace of change, on society is addressed only cursorily in two spots in the 1999 report, *Being Fluent*. The lack of emphasis on these complex issues struck the Teagle group as the single greatest omission of the report. As we discussed our plans to rework the document, we immediately decided to create a fourth and equal category for attention. In many regards, we believe this category is actually the most “teachable” in the context of standard college curricula. In fact, one of the key findings of the group reads:  

*Encourage elective, rather than required, courses on meta-questions such as the history of technology, societal impact, and ethical issues.* Innovative courses of this type can be profitably developed in many different departments, and lend themselves especially to interdisciplinary approaches.

Here is what *Being Fluent* has to say about this nexus of issues. In Box 1.1 on pages 12-13, five “abstract” changes are described as “Possible Social Effects of Information Technology”:

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**Box 1.1: Possible Social Effects of Information Technology**

Information technology has brought or is bringing more abstract or intangible changes than those enumerated in the text.

- **Freedom.** Information technology is an enabler for the opportunity for individuals to express themselves freely, unfettered by intermediaries. For a modest investment in a computer and the nominal cost of a connection to an Internet service provider, anyone can post anything on a personal home page or say anything in a chat room, and the potential audience for such postings is quite large. Such convenient, inexpensive, and sustained opportunities for free speech are unprecedented, as are the dark sides of easy expression (e.g., the ease of disseminating misinformation or disinformation, hate speech, child pornography, and so on).

- **World connectivity.** Information technology is cheap, fast, "point to point," and asynchronous, giving e-mail a convenience and immediacy that postal and telephonic communications have
never had, and a personalization that broadcast media cannot provide. With the World Wide Web, access to local information is possible at unprecedented speeds--one can read the Sydney Morning Herald in Sydney, Nova Scotia, at the same moment that Australians are reading it. The ease with which information technology allows citizens of the world to keep in touch with people and events elsewhere unifies the world profoundly. And this effect will increase as information technology becomes adopted more completely around the world.

- **Loss of remoteness.** A corollary to the world-connecting property of information technology is that information resources are now much more accessible to individuals worldwide. Although the entire holdings of the New York Public Library will not soon be completely online, the information access advantages of those living in geographically remote areas with access to the World Wide Web compare favorably to those living in the Big Apple. The information needed by many people, though perhaps not scholars, is largely available electronically. Telecommuting is another manifestation of information technology's location independence.

- **Alienation.** There is recent, preliminary evidence that even a modest amount of time (one or a few hours per day) spent on the Internet can lead some users to feelings of depression and alienation.¹ An apparent source of some alienation is that "friendships" formed via chat rooms can be more superficial than those formed through face-to-face interaction. In addition, the time spent in front of a screen reduces normal interpersonal contact. This topic requires further study, and if the findings of the Carnegie Mellon University study are confirmed, would suggest the need for attention to the mental health consequences of changes associated with the use of information technology.

- **Predominance of English.** Information technology is largely an English-oriented medium, because its development has followed the English-centric tradition of post-World War II science, and, perhaps more importantly, because the United States has played a dominant role in the deployment of information technology. While information in almost every written language can be

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found on the World Wide Web, a surfer must have at least a passable understanding of English to reap the greatest advantage of information technology globally. The implications for other natural languages are unclear, but it is likely that many world residents will want to be bilingual in the near future.

And on pages 33-34, these issues appear again, buried as Component #10 in the list of Fundamental Concepts. The text reads:

10. Societal impact of information and information technology

The technical basis for social concerns about privacy, intellectual property, ownership, security, weak/strong encryption, inferences about personal characteristics based on electronic behavior such as monitoring Web sites visited, "netiquette," "spamming," and free speech in the Internet environment.

Understanding social issues strongly connected to information technology goes beyond fitness to general principles of good citizenship. Policy issues that relate to information technology, including privacy, encryption, copyright, and related concerns, are increasingly common today, and informed citizens must have a basis for understanding the significance of those issues and for making reasoned judgments about them.

Information technology connects to the world at large in many ways, and characteristics of the technology have implications for everyday issues. Consider, for example, intellectual property. Copyright is accompanied by a well-established body of law, but now that the Web makes images and documents available to a huge audience, it has become much more important for Web users to understand that the ability to see an image on the Web does not automatically imply that the image can be copied or reused.

Numerous other issues are apparent today on which many non-technologists are asked to make judgments. Is the Internet just another form of publication, and therefore subject to the same First Amendment and copyright protections that newspapers enjoy? Is encryption a potential weapon that needs to be kept out of foreign hands? Why are standards important, and how do we promote the use of standards without permitting unregulated monopolies to stifle innovation? Does inviting technologically skilled workers from other countries create or destroy
jobs? How do we encourage children to achieve the highest levels of technological competence? Does information technology cause job displacement and/or upskilling? How is it possible to promote social equity regarding access to information technology?

Because this group, unlike the other three groups, had no list of components to revise, it had the freedom to develop its ideas in the form of a set of questions. This strategy made good sense given the incredible wealth of topics, disciplinary approaches, philosophical quandaries, and cultural distinctions encompassed by this broad category of issues. No list of components could ever hope to capture the breadth of the possible material that could be covered. In fact, a semi-prescriptive list such as those produced by the other three groups would be inappropriate. A set of open-ended questions, which can themselves be focused in almost innumerable ways, seemed the best way to define this category of concerns. There is no claim that this list is exhaustive.

1. How has society been transformed through IT? Sub-questions might include:

   • How has IT changed the political world?
     - Issues may include: elections, campaigning, polling, political organizing, the news media

   • How has IT changed the economic world?
     - Issues may include: private and public wealth, business, banking and financial transactions, shopping, financial modeling

   • How has IT changed the social world?
     - Issues may include: personal communication, entertainment content and media, news, virtual communities, dating, gaming, GPS, pornography

   • How has IT influenced the Arts?
Issues may include digital art forms, remixing, arts distribution and finances, copyright and intellectual and creative property rights, distributed amateurism

• How has IT changed the Sciences?
  • Issues may include computer modeling of systems, data generation and analysis, interdisciplinary connections, simulations

• How has IT changed education?
  • Issues may include new learning technologies and modes, personalized instruction, quantitative competencies, impact on writing, expansion of necessary skills for learning, information retrieval, wikis

• How has IT changed the way we communicate?
  • Issues may include word processing, email, VOIP, blogs, social software, spam, image and file sharing, expanded cell phone technologies

2. What IT practices are ethical and what are not?
  • Is it acceptable to cloak your identity to avoid getting junk e-mail? Is it acceptable to track the location of family members, employees, public officials, or private citizens using GPS on their cell phones? Is it an invasion of privacy to covertly screen e-mail or computer use?

3. How has IT changed people’s values, perceptions, and actions?
  • How has digital surveillance altered behaviors? How have ideas about collective vs. individual ownership of ideas, texts, images, and music changed? How has the web changed perceptions of global community and responsibility?

4. How has IT changed social and legal boundaries?
• How has instant communication altered social organization and behaviors? How has the law had to adapt to the use and abuse of information technology? How have privacy rights changed? What has been the impact of identity theft? What is the impact of the digital divide?

5 How can IT be used to improve society?

• Can IT encourage equality, inform the public, facilitate participation in elections, empower the disenfranchised, promote community, national, and global awareness and participation? Can IT encourage group problem solving (open source software, for example), promote self-education, and facilitate human adaptation to a changing world? Can IT improve security or does it further endanger us?

6. How might IT harm society?

• Does IT encourage racism, pornography, hate speech and other forms of offending or degrading individuals or groups? Does IT encourage theft and facilitate plagiarism? Does IT expose minors to predators, empower pranksters and hackers, and permit dangerous people access to knowledge and the ability to disseminate potentially harmful knowledge? Does IT impinge on individual rights and privacy through the actions of governments or corporations that can track internet use and glean information about citizens/consumers?
Appendix A: Working Group Participants

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Chuck Hedrick, Rutgers University
Susan Lawrence, Rutgers University
Victoria Szabo, Stanford University
Ellen Woods, Stanford University (later of Duke University)
Tim Burke, Swarthmore College
Spencer Benson, University of Maryland
John McDermott, University of Pennsylvania
Kent Peterman, University of Pennsylvania
Hank Dobin, Washington and Lee University
Krysztof Jasiewicz, Washington and Lee University
Jeff Overholtzer, Washington and Lee University
Douglas Kankel, Yale University
4.2 A PROJECT-BASED APPROACH TO DEVELOPING FITness

Although the content of FITness is presented in Chapter 2 as a list of items, such a characterization does not imply that lecturing about them is the optimal form of instruction. FITness is fundamentally integrative, requiring the coordination of information and skills with respect to multiple dimensions of a problem and the need for making overall judgments and decisions taking all such information into account. For this reason, the committee believes the best way to develop FITness is through project-based education. Projects weave together the skills, concepts, and capabilities of FITness to achieve a tangible result. In a project, specific information technologies will be used, motivating students to become skillful with such things as databases, e-mail, and presentation software. Understanding the range of alternatives and implementing the solution will rely on or motivate learning the underlying concepts.

Projects of appropriate scale and scope inherently involve multiple iterations that provide opportunities for instructional checkpoints or interventions. And, an appropriately scoped project will be sufficiently complex that intellectual integration is necessary to complete it. (Appendix A provides some illustrative projects.)

An appropriately scoped project demands collaborative efforts. Project-based collaborative efforts are pedagogically valuable for several reasons. First, developing true expertise in any area requires the individual involved to assume a variety of different roles—creator, critic, partner, supporter, and so on—and a collaborative group effort is a natural setting in which to exercise these roles. Furthermore, learning to specialize and to deliver one’s special information to a group is an important dimension of developing expertise, and so project-based learning helps teach students the character and nature of varied roles as well as how to play the role of a specialist. Second, a project requiring multiple collaborators can be large and complex enough to raise important intellectual and strategic issues that simply do not arise when problems are artificially delimited to be completely doable by a single individual. Third, students benefit from hearing explanations formulated by peers as well as experts.³

A project-based approach is consistent with many different instructional models:

- **Instruction as transmission of information.** In this model, lectures, books, and other materials transmit the information that students need to learn.
- **Instruction as active learning.** This model suggests that students learn best by actively engaging the material through asking questions, answering questions, pushing buttons, doing experiments, or using tutoring programs.
- **Instruction through discovery learning.** In discovery learning, students learn with little direct guidance on the theory that students who “discover” solutions on their own will be more likely to remember and master the competency and be able to apply that competency in like situations. Students who are spoon-fed will frequently not develop the cognitive maps associated with real mastery.

Each of these models can support project-based learning, though in practice no one approach suffices for a successful project. Effective courses need support and scaffolding so individuals can test their understanding against expectations regularly and obtain feedback on their weaknesses.
No single project bestows FITness, but a series of well-chosen projects can provide a foundation for the lifelong journey toward FITness. By working on a number of projects, students will have opportunities to use similar principles of technological solutions in different settings, to recognize technological analogies, to develop reasonable expectations for technological solutions, and to find work-arounds when technology falls short. A series of projects can provide sufficient breadth and diversity of experience that students can realistically “learn the rest” on their own, thus providing the intellectual foundation for self-directed, lifelong learning that can occur in many non-classroom settings.

Undertaking projects in complex problem domains provides a natural context in which FITness can be developed. For effective pedagogy, problem domains must be personally relevant so that the learner has reason to revisit and redefine his or her understanding of information technology. Individuals must use information technology in a domain they understand in order to develop FITness, but as long as that domain is relevant to the individual, it does not matter which domain is involved.

Finally, the description of capabilities, concepts, and skills described in Chapter 2 naturally raises for many educators the question of how much time is needed for each capability, concept, and skill in a time-limited curriculum for students to promote FITness. However, because FITness is a continuum, a specific educational context is needed to answer this question concretely. A course promoting FITness for history majors may well have a different weighting of topics than a course promoting FITness for engineers. A mini-course taught in an “independent activities period” designed for first-year students without designated majors is certain to be structured differently than a two-semester course for graduating seniors. Such matters are best handled by those who know the resource constraints of time and the availability of computing resources, as well as the competing needs, how the knowledge and skills are likely to be applied, and the value of deeper understanding to other student objectives.

The treatment of the three components of FITness—skills, concepts, and capabilities—may be approached differently. Students can learn word processing through the need to prepare and submit essays, spreadsheets or databases through the need to manipulate data in science courses, and so on. Many students will develop some of these skills prior to college, but even those who do not will have considerable motivation to learn them. College students have many non-curricular opportunities to develop current information technology skills, such as reading self-instruction books, learning from friends, or taking college or university workshops and non-credit courses taught by non-faculty professionals, e.g., computing center professionals and librarians.

The fundamental concepts are somewhat harder to integrate into standard curricula. However, as instructors develop and structure their courses to use information technology for enhanced pedagogical effectiveness, it will be increasingly possible to take advantage of the opportunities thereby provided for discussing the fundamental concepts and the application of these concepts in terms that are relevant to the disciplinary content of those courses. For example, art students study images, and often these images are images on a computer screen. But understanding the fidelity of these images to the originals requires an understanding of how images can be digitally represented. A business course might use computer simulations to demonstrate business processes. But understanding the limitations of a simulation requires understanding how processes can be modeled and the nature and scope of their limitations.
The capabilities also warrant being taught as part of disciplinary or departmental instructional programs. Indeed, these capabilities contribute both to FITness and to developing analytical skills that are necessary for success in multiple disciplines. The mode of instruction is primarily through projects that serve the purposes of the domain yet offer students the opportunity to learn and/or exercise the ten capabilities.
Appendix C: Print and Web Resources

- Academic Technology Center at Cornell University
- Associated Colleges of the South Information Fluency
- American Association of School Librarians Information Literacy
- Being Fluent with Information Technology
- Calvin College—Building Information Technology Fluency into a Liberal Arts Core
- EDUCAUSE Study of Students and Information Technology, 2005: Convenience, Connection, Control, and Learning
- Educational Testing Service Literacy Assessment
- Fluency in Information Technology - Cross Curricular Initiatives - Faculty Technology Resources - UMUC
- George Mason University - Tech Across Curriculum Goals
- George Mason University - Looking for the Logos in Technology
- Institutional Assessment and Studies - Reports: Computer Technology Competency
- International Society for Technology in Education
- Information and Communication Technology Literacy
- Milken Family Foundation - Education Technology
- North Carolina State Information Technology Fluency
- NITLE
- University of Texas Science, Technology, & Society
- Lawrence Snyder, Fluency with Information Technology: Skills, Concepts, & Capabilities
- Milken Family Foundation Technological Fluency
- Technological Fluency Institute Online Learning, Testing, and Certification
- The Teagle Foundation
- University of Washington BeneFIT
- University of Maryland Baltimore County Policy on Technology Fluency
- University of Maryland Baltimore County Strategic Plan for Information Technology
- University of Pennsylvania Examining Technology Fluency
- University System of Maryland Information Technology Fluency Reports
- Washington and Lee University Teagle Site