4. Networking Tools
Social networking tools (such as Facebook, YouTube, weblogs, wikis) facilitate the sharing of content by users. They reflect a fundamental shift in agency, from teachers who broadcast information, to students who generate content. Network tools facilitate individuals to learn within communities, communities to construct knowledge, and communities to learn from one another. Research should support teachers to become active members of communities of practice, and students to engage in continuous learning.

5. User Modeling
User modeling techniques represent student competencies and learning achievements, including content skills (e.g., mathematics), learning skills (e.g., asking for help, understanding questions), personal interests, learning goals, and affective characteristics (traits and emotional states). User models track when and how skills were learned and what pedagogies worked best for each learner.

We recommend research into machines that learn, or the ability of a system to acquire new knowledge through observation of students and to improve its teaching by learning rather than by being programmed, to augment user models automatically and continuously and enable systems to adapt to new student populations.

6. Mobile Tools
Wireless devices provide remote access to information and enable social interactions to take place any time and anywhere. Ubiquitous access enables students to be in seamless learning modes wherever they are (e.g., stationary or moving), whenever they wish (e.g., synchronous and asynchronous with others), whatever their environment (formal and informal settings), and with whomever might be appropriate (for example, known and anonymous participants). Research should identify how to enhance these tools to provide student ownership and control over their goals.

7. Intelligent Environments
Intelligent environments integrate artificial intelligence techniques (for example, modeling, natural language, machine learning) into educational software to customize it to fit students’ personal needs and abilities. Agents and active objects will learn about students and allow learners to move seamlessly between real and virtual worlds. Research should determine whether intelligent agents and environments are more motivating; how to enable them to automatically adapt themselves to fit each learner; how they should explain themselves to learners; and how authors can design, assemble and orchestrate them.

This work was supported by the Computing Community Consortium, which is managed by the Computing Research Association (CRA) and funded by the National Science Foundation (NSF) through award # 0637190.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or CRA. Publication date: June 2010.

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A Roadmap for Education Technology

This brochure describes the initial findings of two workshops that considered the future of education and in particular the role of computational technology in education. These discussions were part of Global Resources for Online Education (GROE), a project sponsored by the National Science Foundation through the Computing Community Consortium.

Workshop members were guided by the view that cyberspace can be a collaborative and cognitively supportive learning space for a changing future. Our goal is to improve education for all people (youth as well as adults), at all levels (school, college, professional development), across all locations (home, work, institutions) and in all types of activities (work, recreational and hobby-related).

We identified seven grand challenges for the future of education and as many promising technologies. We now need long-term efforts in research and applications championed by federal agencies in both education and computational science. This brochure provides an overview and brief summary of these discussions. Recommendations for federal funding of this research are provided in the full GROE report, see Final Project Report at www.cra.org/ccc/groe.php

1. Personalized Instruction

Education will be personalized to harmonize with each student’s traits (for example, personality, learning style) and states (e.g., affect, level of engagement). Computational tools will understand an individual’s strengths, weaknesses, challenges and motivational style as might a human tutor. Research should help identify which pedagogies are best for each individual’s traits and states.

2. Assessment

Assessment will be fun, immediate and accessible. It will record student competencies:
- to improve learning capacity;
- to identify what is learned; and
- for purposes of teacher accountability and student promotion.

Beyond the current model of Teach and Test, it will constantly feed back results into learning. Research should help identify student competencies and reason about how assessment flows to, from and with learning.

3. Social Learning

Social learning will involve continuous connection among student team members and be accessible wherever students are located. Students will choose to collaborate within a team or work on their own. Technology can sustain continuous and active learning and enable students to communicate anywhere. Research should focus on how learning communities share, sustain and build on knowledge.

4. Beyond the Classroom

Education will be seamless, ubiquitous and pervasive across places of study (home, work, institutions), educational levels (school, college, university), types of learning (formal and informal), and personal ability (special and typical students). Research should focus on supporting students to apply, enhance and transfer their knowledge and skills across boundaries, and to learn continuously.

5. Alternative Teaching

Education will prepare students for a changing future, where, in addition to learning about disciplines (for example science, history, and art) students also learn soft skills (for example, creativity, critical thinking, communication, and self-direction). Students should practice solving complex problems in innovative ways and think about vast amounts of interconnected knowledge. Research should identify teaching methods that support students ability to work across disciplinary domains and in collaboration with others.

6. Stakeholder Involvement

Stakeholders (teachers, students, parents, administrators) will play new roles in connection with technological tools. Significantly more information will be available about students, and stakeholders will begin to trust technology to do what it claims to do, including assuring absolute privacy. Research should develop higher quality information for teachers, identify how to inform their pedagogical decisions, and identify activities that make teachers’ experiences as engaging as that of children.

7. Policy Changes

Education will be a civil right for people worldwide. It will become global, freely available and an engaging opportunity for all. People will learn rapidly and quickly and form new learning communities. Research should explore how to support broadly-based, systemic changes in education, modeled after social movements and sustained over protracted periods of time.

Promising Technologies

1. Serious Games

Serious games combine fun and learning. Mental exercises and entertainment are integrated along with exciting interfaces (e.g., immersive environments, natural language conversation) and possibly physiological tracking (e.g., to detect good listening skills and non-verbal leadership behaviors). Research should discover if games are inherently more motivating than other computer learning environments and whether “soft skills” (for example, leadership and cooperation) transfer from games to the real world.

2. Data Mining

Data mining involves methods for storing and reasoning about educational data to understand students’ knowledge, assess their progress, and evaluate learning environments. Data from lifelong chronicling of student learning provides insight into how people learn and suggests effective pedagogical strategies for classes of students, for example, knowledge about how clusters of children with similar problems behave. Research should focus on tools, repositories and methodologies to shed light on education and psychological questions and to address the deluge of data, by developing new data mining, security and database techniques.

3. Rich Interfaces

Rich interfaces include technologies that sense, analyze and recognize human action, whether cognitive, meta-cognitive or affective. Sensors may include radio frequency identification (RFID), speech technologies, cameras, pulse and posture sensors, global positioning systems (GPS), smart phones, and longitudinal and comprehensive logging. Virtual agents may include embodied and robotic creatures that present as peers and offer engaging social support and advanced scaffolding. We recommend research to develop innovative interfaces (for example, sensors, vision, object recognition and augmented manipulatives) that allow learners to move seamlessly between real and virtual learning environments, and research to accommodate full sensory input into either.