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Commentary: Reactions to Bull, Bull, Garofalo, and Harris

JULIE GESS-NEWSOME
Northern Arizona University

"Grand Challenges: Preparing for the Technological Tipping Point" by Bull, Bull, Garofalo, and Harris (2002) presented a strong message about the coming age of ubiquitous computing and provided concrete evidence of the necessity for educators to be ready for this new era. The case for the inevitable explosion of computing resources in the schools is clearly made, as well as the challenges that may lie in this technological wake. The article provided concrete examples of educational amplifiers and the dangers of entrenchment, and acknowledged the didactic digital divide that can occur based upon the preparation of teachers. What the article did not address is a perhaps the greatest challenge to the successful accommodation of technological resources. For ubiquitous computing to positively impact teaching and learning, a new vision of teaching and learning—a pedagogical paradigm shift—is needed.

The history of reform in science education over the last 200 years is fairly dismal—our biggest "inventions" have been structural: compulsory education, the creation of the junior high, and the movement away from "natural sciences" to the earth science-biology-chemistry-physics sequence so often seen in today's schools (DeBoer, 1991, *A History of Ideas in Science Education*, is an excellent resource on this topic). As one examines these "revolutions," it becomes apparent that each was driven by social rather than pedagogical change (an unskilled workforce that needed to be acculturated, a

need to decrease the size of schools and increase a factory-like atmosphere, and the pressure to prepare students for college and academic occupations versus vocational pursuits).

Ubiquitous computing has the potential of being another such social force that will change the complexion of public schooling. But despite structural changes, the teaching of science has not changed substantially in the last 200 years. Why? The article mentioned two reasons that are as applicable in the past as they are today: entrenchment and the uneven preparation of teachers. In the past as today, teachers were never prepared to teach differently despite the change in the structure of schools. As a result, teaching science today is essentially the same as it was in the era of the one-room schoolhouse. Teachers did not seize the opportunities that existed to change the way they taught, nor were they convinced of the need for a new vision of what it means to teach and what it means to learn. Today, many teachers and students still believe that their job is to teach and learn isolated facts, repeating those facts on command. As long as this definition of teaching and learning remains dominant, ubiquitous computing will never gain a pedagogical foothold beyond being an electronic page-turner, delivering facts to be memorized more quickly and from more diverse sources than in the past.

Most of the new content standards (science, as well as mathematics, social studies, etc.) argue that the goal of education today should be to create a public who can gather and interpret data in a critical and rational way and then use that information to make decisions. If teaching and learning is viewed from this vantage point, ubiquitous computing becomes an answer to a need rather than a tool to be incorporated for purposes of control and regulation; technology can thus expand (educational amplifiers) rather than contract (entrenchment) access to the world, increasing access to human potential and removing barriers of distance and (often) time. What is missing is not the technology (though reaching the "tipping point" with appropriately designed pedagogical tools will certainly help many see the potential of thinking about education in new ways), but a pedagogical purpose that values questioning, collecting data, judging the adequacy of the data collected, synthesizing ideas, and justifying decisions. In other words, as a society (and a teaching public), we need to recognize and honor the dynamic nature of knowledge creation and application rather than the static accumulation of

facts (maybe we haven't fallen all that far from the olive tree in Greece after all!).

How do we get to this new pedagogical vision that dynamically employs the power of ubiquitous computing to its full potential? One answer may lie in access, time, and creativity. Talented and forward looking teachers need access to new technological innovations, be given the time to master them, and be given the freedom and support to dream about how these tools can best be used in support of their student's learning. Teachers will be the best prophets in their own land. The second answer lies in the creation of a focused research agenda on the appropriate uses of technology and the currently unrealized gains that may be possible in student learning.

Finally, the critical factor in the appropriate use of technology will be the creation of a pedagogical paradigm shift resulting in new visions of what it means to teach, know, and learn.

Contact Information:

Julie Gess-Newsome
Northern Arizona University
julie.gess-newsome@nau.edu