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The future of citizen science: emerging technologies and shifting paradigms

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Abstract: When combined with new technology, citizen science bridges the gap between academia and the general people, opening up previously inaccessible areas of ecological study and civic participation. We take a look at the research methods, program and participant cultures, and scientific communities that will make up citizen science in the future using representative technology and other instances. There will be practical programming hurdles ahead for future citizen-science programs, and socio-cultural concerns surrounding new technology will certainly have an impact. We provide suggestions to assist project managers be ready for the problems that lie ahead, and we think that networked, open science and online computer/video games will be powerful instruments to attract non-traditional audiences. Ecological research and public education may both benefit from a better organized citizen-science activity that makes use of cyberinfrastructure, journals, and networked groups and alliances.

Keywords: multiple spatial, temporal, andsocial scales

INTRODUCTION:

The above vignette illustrates, the future of citizenscience will likely be inextricably linked to emerging technologies. By sanning multiple spatial, temporal, andsocial scales, and by being designed to achieve a number ofdifferent outcomes, citizen-science projects will need toadopt new technologies to allow participants and organizersto communicate and interact effectively (Bonney *et al*. 2009a; Newman *et al*. 2011; Dickinson *et al*. 2012; Miller-Rushing *et al*. 2012; Shirk *et al*. 2012). As citizen science becomes more formalized and more widely accepted amongscientific, educational, and community-oriented domains, additional factors – such as sociopolitical scenarios, eco-nomic conditions, and ethical considerations – will also influence how the field develops over time. Here, we discuss the future of citizen science (ie the process it uses to conduct scientific research, the culture of its future participants andprograms, and the growing citizen-science community) using representative technologies and examples from the vignette above.

Emerging technologies New technologies, such as mobile applications (apps), wire-less sensor networks, and online computer/video gaming, show great promise for advancing citizen science. Mobileapps involve software developed for use on portable devices.***Figure 1.*** *Screen capture images of the Project BudBurst mobile application illustrating integrated tools to improve data collection and motivation. The mobile application automates capture of an observer's location, uses standardized plant lists and associated phenophase (periodic life-cycle event) definitions, provides data-entry forms for single reports, and offers a game ("Floracaching") to increase motivation for participants to return.*

across projects. Some projects involve participants in a single step of the research process, whereas others involve participants in multiple ways (Danielsen *et al*. 2009; Dickinson *et al*. 2012; Miller-Rushing *et al*. 2012). Despite these differences, the typical research process for most citizen-science projects has been conceptualized as:gathering teams/resources/partners, defining research questions, collecting and managing data, analyzing and interpreting data, disseminating results, and evaluating program success and participant outcomes (Bonney *et al*.2009a). We examine how each of these processes may change in the future.

Gathering teams/resources/partners

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Innovative uses of existing technology may expedite team formation, improve the ability of program coordi- nators to locate professional scientists, help programcoordinators to identify participants, and assist profes- sional scientists and program coordinators with locat-ing required resources. Existing databases – such as Citizen Science Central, SciStarter, and the Citizen Science Alliance – offer information about best prac-tices, training materials, and searchable databases that help individuals find projects, resources, and partners. The expansion of these tools and continued advancesin social media use will facilitate participant connec- tions and provide opportunities for developing new projects based on freely available and scientifically vet- ted protocols and evaluation practices. For example, the event organizer in our vignette communicated with potential participants via social media, and volunteers used online social networks to validate data through mobile identification and reporting tools. Improved use of networked databases, social media, and cyberinfra- structure integrated into a more formal enterprise.

Defining research questions

Research questions can be formed through top-down (sci-entist-driven) or bottom-up (community-driven) processes (Danielsen *et al*. 2009). Current technologies stimulate cre-ativity for both approaches. Participants may develop new questions aided by data visualization or scientists may seepreviously insurmountable challenges – such as geolocatingplace names, topographic features, and transportation net-works – as achievable given a number of now-available "citizen sensors" (Goodchild 2007). The Zooniverse(www.zooniverse.org), a suite of scientist-driven projects, allows individuals to register, join one or more projects, and become de facto members of project teams (Clery 2011).Likewise, citsci.org (www.citsci.org) supports the formationof bottom-up and top-down projects on local, regional, ornational scales, while also allowing for scientific discoverythrough meta-analyses of data integrated across different projects (Newman *et al*. 2011). Mobile apps and social media may provoke more creative discussion of research questions through real-time dialogue between scientists andcitizens. For example, Naomi's sedge report in our vignettemay prompt Jose to discuss the observed trend in species richness with a colleague who, in turn, asks questions about how that trend may correlate with climate change.

Collecting and managing data

New and existing technologies will improve the rate and quality of data collection through location-based, real-time mapping services (Lwin and Murayama 2011). For instance, Project BudBurst's mobile app (available at http://neoninc.org/budburst/gomobile.php) simplifies data

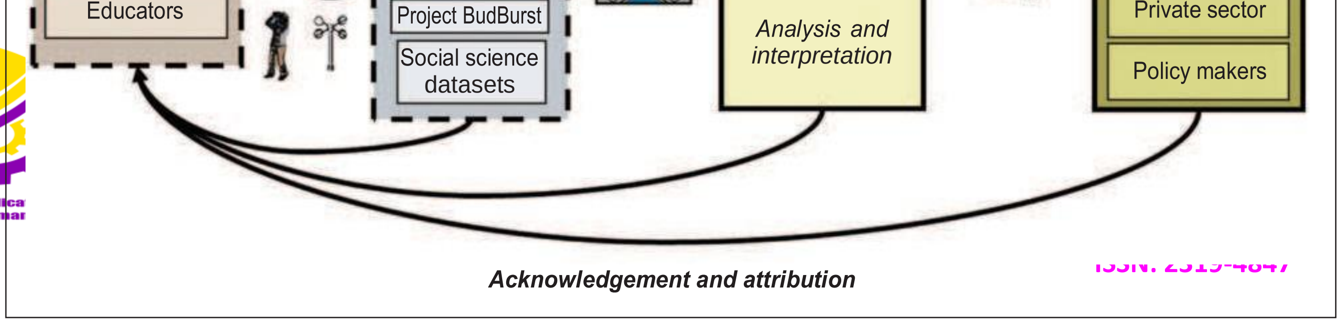

*Figure 2. Data contributed by various providers – such as citizen scientists, researchers, and graduate students – submitted to online data repositories (eg eBird, Zooniverse) make citizen-science data accessible. Increased investment in data exchange protocols, web service-based Application Programming Interfaces, and metadata documentation, such as the work being done by the Data Observation Network for Earth (DataONE), will increase the ability of scientists to re-use and re-purpose data. Results of analyses and visualizations performed through consolidated data that attribute contributors will increase the value of citizen-science datasets.*collection by automating the capture of a participant's loca- tion (Figure 1; Graham et al. 2011). Additionally, wireless sensor networks enable chlorophyll and temperature profil- ing data to be automatically collected by automated moni- tors along lake transects (Cuff et al. 2008). Mobile phones are being transformed from communication tools to "net- worked mobile personal measurement instruments" (Wobbrock 2006; Paulos et al. 2008). Undoubtedly, tablet computers will operate faster and have greater functionality in the future, and as-yet-unimagined portable devices will be invented. Augmenting data collection with behavior- and context-aware alerts (eg location-aware alerts notifying data collectors that a given species observation is outside the normal range), for instance, is already occurring (Kim et al. 2009), and inexpensive "add-on" sensors that plug into mobile devices will likely become commonplace (Kuo et al. 2010). In the future, more ubiquitous computing will very likely occur (York and Pendharkar 2004).

The methods (eg Kelling *et al*. 2009). The overall volume of data generated will lead to opportunities for data re-use and meta-analyses but may also present novel challengesrelated to "data deluge". Today's cyberinfrastructure investments in metadata, attribution, standardization,interoperability, and data curation and preservation will increase the value of citizen-science datasets, not only forscientific research but also for decision support, educa- tion, outreach, and improved scientific literacy.

Analyzing and interpreting data

Addressing the challenges posed by analyzing large- scale data will promote innovation in statistical analysis and modeling (Kelling *et al*. 2009). Grid and cloud com- puting will undoubtedly expand data storage and ana- lytic capabilities, while improved browser-based visual-ization and analysis tools will allow participants to examine data more freely. In our vignette, for example, Jose's ability to integrate new reports with historical data and specify what to visualize (ie animated species richness changes through time) illustrates improved customization of analyses, where users can specify the data, along with independent and dependent variables, to be analyzed. Moreover, citizen scientists carrying mobile, networked, air-quality-monitoring devices could collect and interpret air-quality data as they walk around a given site (Willett *et al*. 2010); in such a sce- nario, participants might overlay these data with loca- tions of known pollutant sources, thereby determining.

Disseminating results

The use of existing technologies (eg social networking) and the adoption of emerging technologies will enhance the ability of scientists and practitioners to centrally con-solidate scientific information across projects, promote col-laborative writing, and create virtual forums and commu-nities (Hoffmann 2008; Waldrop 2008), thus increasing collective capital (Chiu *et al*. 2006; Chang and Chuang 2011). Automated feedback to participants about their data, how those data are used, and project results will become more accessible. As new information flows to interested audiences and feedback is received, knowledgesharing may advance well beyond what is currently possi-ble. However, some of these same approaches may be moresusceptible to bias and inaccuracies, making it important todistinguish scientifically valid information from opinion and/or advocacy (Grorud-Colvert *et al*. 2010). Well- designed "wiki" models that offer open peer-review forumsmay help to maintain data integrity (Hoffmann 2008). The success of such approaches is dependent on diverse stakeholder contributions, yet academic researchers cur- rently neither are rewarded nor have any incentive to con-tribute to these types of projects. In the near future, suchcontributions will hopefully be as valued as publications interms of advancing scientific careers; this would, for instance, benefit the experts who corroborated Naomi's report in our vignette.

Evaluating program success and participantimpacts

Participants in citizen-science programs demonstrate greater scientific knowledge, skills, and positive attitudestoward science and the environment than the general public (Brossard *et al*. 2005; Bell *et al*. 2008; Bonney *et al*.2009a). However, it is difficult to assess changes in mul- tiple impact categories (eg attitudes, behavior) over the course of an individual's participation when such data are lacking (Crall *et al*. 2012). Adjustments in the waywe collect social science data will also help to advance citizen science.
Standardized and electronically availableimpact measures will enable comparisons across diverseprojects. Allowing project managers

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to customize evalua-tions through standard measures will improve the abilityto collect large volumes of quantitative data, while othertools, such as blogs, will continue to provide qualitative data. New technologies may ultimately provide moreefficient ways to track individuals as they participate in awide array of informal science education programs throughout their lifetime, while at the same time pro- tecting participant privacy. Such improved trackingmethods may reveal patterns in the ways that users col- lect data and provide a better understanding of user.What will future program and participant cultureslook like?

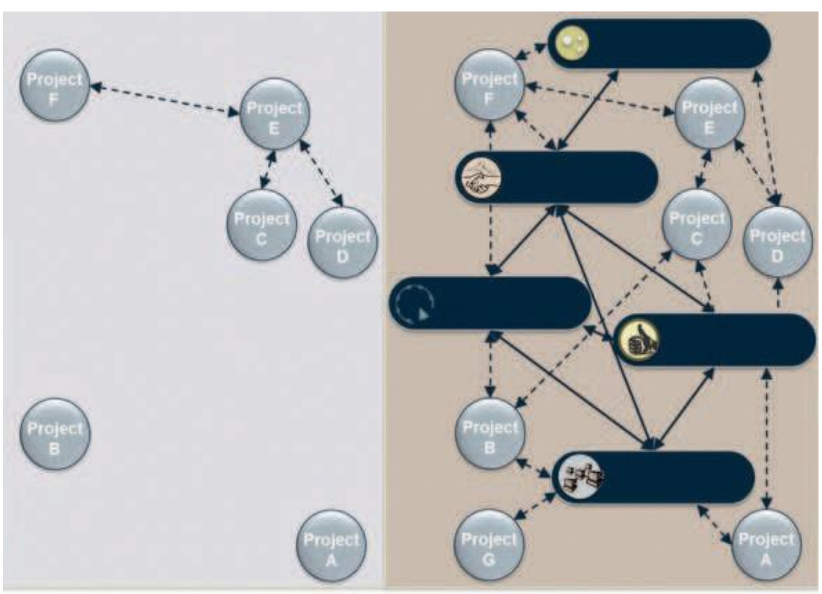
Attributes of "successful" citizen-science programs include fostering long-term community-level involvement and activities, making use of appropriate cyberinfrastructure, developing diverse goals and evaluation strategies, engag-ing under-represented audiences, ensuring projects' finan- cial stability, and effectively disseminating results (Bonney*et al*. 2009b). Emerging technologies will likely influence these and other aspects of the program and of participantculture, such as ethnic diversity and volunteer motivationand retention. We encourage managers of future programsto think critically about current technology adoption andto be open to experimenting with and exploiting new technologies as they emerge.

Diversity of participants

Emerging technologies will broaden participation in citi- zen science in ways that were not previously possible and, if used appropriately, will allow data collection by communi-ties who traditionally remained uninvolved in scientific projects. For example, Worthington *et al*. (2012) describedthe Evolution MegaLab, where participants solicited from15 European countries surveyed shell polymorphism in two species of banded snails, *Cepaea nemoralis* and *Cepaea hort-ensis*. Through the use of open-source software, a team ofcollaborators, and crowd-sourcing approaches, program materials – translated into 13 different languages – engaged6461 people. Yet, diversifying participation remains an elu- sive goal for most projects. Despite their broader reach, new technologies may inadvertently create barriers that widen the "digital divide" between those adopting/havingthe technology and those avoiding/lacking it (Ess and Sudweeks 2001). Furthermore, different beliefs about howwe advance science, what scientific methods ought to beused to improve our understanding, and how we share information across international boundaries may confound data sharing and data re-use, limiting long-term benefits (Pulsifer *et al*. 2011). As citizen-science programs adopt new technologies, sensitivity to social, cultural, economic, and political factors will be critical to the success of pro- jects that cross boundaries and involve local/traditional ecological knowledge (Ballard *et al*. 2008).

The motivation and retention of volunteers

Participants are motivated by contributing to authentic scientific research, by the social interactions such partici- pation affords (Van Den Berg *et al*. 2009), and, in online-gaming contexts, apparently by competition and sym- bolic rewards, such as badges (Cooper *et al*. 2010; Clery 2011; Darg *et al*. 2011). ***Figure 3.*** *(a) Existing citizen-science enterprise where some projects interact and learn from each other and some may not. (b) The same scenario shown in(a) augmented with five new elements of a more formalized citizen-science enterprise, including: local, regional, and global organizations; professional associations; open-access, peer-reviewed journals; resources for best practices; and expanded cyberinfrastructure support systems. The future shown in (b) will be poised to better support the myriad existing and future projects (such as the new project labeled "Project G") that span multiple spatial, temporal, andsocial scales, and that focus on diverse subjects.*



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The future of citizen science will be affected by, among other factors, networked and openscience and the use of gaming to encourage participation by younger and more ethnicallydiverse participants. Networked and open sci-ence is transforming how scientific discoveriesare made (Nielsen 2012). Where traditional citizen-science projects may have included field trips to collect water-quality data or plan motivation, pitting teams against teams and individu-als against individuals, as in the popular online Fold-It game (Cooper *et al*. 2010; Graham *et al*. 2011). Enjoyment is an intrinsic underlying motive for partic- ipation (Nov *et al*. 2011). As teams of scientists and volunteers form, they learn from and become moti- vated through their collective capital. Gaming and a sense of camaraderie make scientific exploration anddiscovery enjoyable; the potential influence of gamingon participant motivation shows the importance of incorporating recreation into citizen science. In one likely outcome based on our vignette, Naomi and the team of volunteers take pride in contributing to sci- ence and may even count their reports through time, comparing their "score" to those of other teams con- ducting similar monitoring.

Panel 1. Recommendations for projects

- Choose appropriate technology for your participants
- Evaluate new technologies with make-versus-buy and cost–benefit analyses, paying particular attention to reliability
- Adopt well-established, well-documented, and well-supported technologies
- Consider interoperable, customizable, open-source solutions where possible
- Follow best practices and use standardized data-collection and data-management protocols where available

advances in the field through annual meetings, encour- ages open dialogue, publishes an open-access peer- reviewed journal centralizing associated literature, and generally serves to guide the field. A "network of data networks" and regional "citizen-science centers" could also maintain interconnected databases listing pro- grams, best practices, standardized protocols, and vetted training materials; deliver cyberinfrastructure support for data management; offer complex analysis and visual-ization tools; and provide forums for theoretical, empiri-cal, and technological advances (Figure 3).

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Panel 2. Recommendations for the emerging field ofcitizen science

- Embrace both centralized national programs and decentral-ized local efforts
- Encourage creative enthusiasm to increase likelihood of suc-cess of citizen-science projects at large and small spatial andtemporal scales
- Encourage use of open-data standards and open-source soft- ware (code that is free to use and can be changed by others toadvance the code base)
- Seek broad and diverse participation through local and tradi- tional ecological knowledge
- Maintain a cooperative and supportive environment for all programs, practitioners, and participants, realizing the value of each to the advancement of the field

REFERENCES:

Collins, D., Ballard, HL, and Trettevick, JA (2008). Studying two communities on Washington's Olympic Peninsula—one home to immigrants and the other to Native Americans—and comparing participatory ecological research in both. This is in the volume edited by Wilmsen, Elmendorf, Fisher, and others. Empowerment via partnerships: study that involves community members in managing natural resources. Earthscan: Richmond, Virginia and London, United Kingdom.

Bell S, Marzano M, Cent J, and colleagues (2008). Who or what matters? Organisations and individuals working as volunteers to document and track biodiversity. Protecting Biodiversity, 17(3443–54).

R. Bonney, H. Ballard, R. Jordan, and colleagues. 2009 (a). The public's role in scientific inquiry: a field definition and an evaluation of its possible applications to non-formal science education. A report from the CAISE investigation panel. Book published by CAISE in Washington, DC.

Brady R, Dickinson J, Cooper CB, et al. 2009 second block. A new resource for increasing scientific understanding and scientific literacy is citizen science. 59: 977–978. See BioScience for further details.

Lewenstein B, Bonney R, and Brossard D. (2005). The influence of a citizen science project on scientific knowledge and attitudes. International Journal of Science Education, 27: 1099-121.

Chuang SS and Chang HH 2011. The moderating role of social capital and personal motives in the context of information sharing. Information Management 48: 9-18.

Wang ETG, Hsu MH, and Chiu CM (2006). Integrating social cognitive and social capital theories to understand knowledge exchange in virtual communities. Decision Support Systems, 42, 1872–188.
D. Clery. 2011. Volunteers at the Galaxy Zoo explain the highs and lows of scientific inquiry. Nature 333: 173–75.
Cooper S, Khatib F, Treuille A, and colleagues (2010). Using a multiplayer online game to predict protein structures. Science 466: 756-60.
Collaborators: Crall AW, Holfelder K, Waller DM, 2012. The effects on participants' mindsets, actions, and level of scientific literacy of a citizen science training program on invasive species. Journal of Public Health; DOI: 10.1177/0963662511434894.
Journal Article: Cuff, Hansen, and Kang (2008). Urban sensing: no longer lost in the woods. The Commun. ACM is published in volume 51, issues 24-33.
In 2009, Danielsen F, Burgess ND, Balmford A, and others published. Methods for involving local communities in the monitoring of natural resources. Protected Biology 23: 31–42.
Jensen PM, Burgess ND, Pirhofer-Walzl K., and Danielsen F. 2010. The level of human engagement determines the scope and pace of environmental monitoring. Applied Ecology 47: 1166–1168.
Galaxy Zoo: multi-mergers and the Millennium Simulation in 2011 by Darg DW, Kaviraj S, Lintott CJ, and others. The citation is from the Montanus astronomical journal, volume 416, pages 1745–1755.
James L. Dickinson, John Shirk, David Bonter, and colleagues, 2012. The present situation of citizen science as a method for environmental study and community involvement. Environmental Frontiers 10: 291–97.
Authors: Ess and Sudweeks. 2001. Near the periphery - cultural impediments and facilitators of information technology (IT) dissemination in underserved and rural areas. Publishing in the New Media Society, volume 3, pages 259–269, 2006.
The authors are Graham, Henderson, and Schloss. 2011. Concise report: involving citizen scientists in geosciences research with mobile phones. Proceedings of the American Geophysical Union 92: 313–315.
Group K: Grorud-Colvert, Lester SE, Airame S, et al. 2010. Communi- cating marine reserve science to broad audiences. P Publication: National Academy of Sciences, USA, 107: 18306-11.
For the year 2008, Hoffmann R. A collaborative wiki for the field of life sciences that values originality. The National Journal of Genetics, 40: 1047-1051.
With contributions from Hochachka WM, Fink D, Kelling S, and others. 2010. A new approach to studying biodiversity: data-intensive research. Biology 59: 613–620.
Dombrowski C., Thomas T., Kim J., and Lee E. in 2009. The situation of alternative reality games from 2001 to 2009 as an example of narrative in new media. On Monday, the 14th;
www.firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/viewArticle/2484/2199.
Computing location privacy: a literature review (Krugmm, 2009). Published in Pers Ubiquit Computing 13: 391–399.
"Hijacking power and bandwidth from the mobile phone's audio interface" was published in 2010 by Kuo Y-S, Verma S, Schmid T, and Dutta P. The proceedings of the first annual symposium on computing for development were published in DEV'10. [Davis, 2010] (London, UK: DEV'10); doi:10.1145/1926180.1926210.
Murayama Y. and Lwin KK. 2011. mobile phone-based web-based geographic information system for collecting data in the field in real-time. Public engagement in ecological research: a historical perspective. Journal of Geographical Information Systems, 3(3), 382–389, Miller-Rushing A, Primack R, and Bonney R. 2012. Environmental Frontiers 10: 285-290.
With contributions from Graham, Laituri, Crall, and Newman. 2011. Support for citizen research on several scales: the art and science. Environmental News 6: 217–27.
In 2012, Nielsen published a thesis. Exploring new frontiers: the age of interconnected scientific inquiry. Princeton University Press, Princeton, New Jersey.
Anderson, D., Nov, and Arazy, O. 2011. "Dusting for science": inspiring and involving digital citizen scientists in 2011. The 11th annual iConference took place from February 8th to the 11th, 2011 in Seattle, Washington, USA. The Association for Computing Machinery is located in New York, NY.
This work was authored by Paulos, Honicky, and Hooker. year 2008. Engaged citizens: paving the way for collective city planning. As an editor, Foth M. Communities: integrating and implementing urban information systems. The Information Science Reference published by IGI Global is located in Hershey, Pennsylvania.
Harris A., Taylor D.R.F., Laidler G.J., and Pulsifer PL. 2011. Reflections on experiences establishing an atlas of sea ice knowledge and

International Journal of application or Innovation in engineering and management
ijaiem.com/Feb 2021/ Volume 10/Issue 1/Article No-1/32-39
ISSN: 2319-4847

use: Towards an indigenous data management program. Geogr. Can 55: 108-24.
"Diffusion of innovations" (third edition, 2003) by Rogers EM. The Free Press, New York, NY.
Authors: Shirk JL, Ballard HL, Wilderman CC, and others. 2012. A paradigm for purposeful design: public participation in scientific research. "Ecology and Society" 17: 29
Adults' reasons for engaging in conservation education and volunteering outside of formal settings: programming implications (Van Den Berg, Dann, & Dirkx, 2009). Environmental Education Today 8: 6–17.
Walters, M. (2008). Nature 455: 22-25. Big data: wikiomics. Contributed by Willett, Aoki, Kumar, and colleagues in 2010. The common sense community: assisting first-time mobile data analysts.
Computer Science Lecture Notes May: 301–18.
"Wobbrock JO." 2006. Exploring the potential of mobile devices in human-computer interaction of the future. "What is the Next Generation of Human-Computer Interaction?" was the topic of the CHI workshop's proceedings. Montreal, Canada; April 22–27, 2006.
Valuentown J, Worthington JP, Cook L, et al. 2012. Experimenting using citizen scientific methods: Evolution MegaLab. Guidelines for Environmental Evolutionary Methods 3: 303–09.
Judge York and Plaintiff Pendharkar. 2004. Questions of human-computer interaction pertaining to mobile computing .