Dagstuhl Manifesto

Dagstuhl Perspectives Workshop 09142

Preventing the Brainware Crisis

Editors: Stephan Diehl, Universität Trier, Germany
Ulrike Stege, University of Victoria, Canada

Contributors: Roswitha Bardohl, Schloss Dagstuhl, Germany
Torsten Brinda, Universität Erlangen, Germany
David Blades, University of Victoria, Canada
Gordon Bolduan, Heise Zeitschriften Verlag, Germany
Stephan Diehl, University of Trier, Germany
Michael Fellows, University of Newcastle, Australia
Annette Leßmöllmann, University of Applied Sciences – Darmstadt, Germany
Todd Milford, University of Victoria, Canada
Frances Rosamond, University of Newcastle, Australia
Ulrike Stege, University of Victoria, Canada
Karl Schoder, PH Niederösterreich – Baden, Austria
Andreas Schwill, University of Potsdam, Germany
Achim Wagner, Bundesagentur für Arbeit – Trier, Germany

Abstract

This manifesto summarizes the outcomes of the Dagstuhl Perspectives Workshop "Preventing the Brainware Crisis" held in Spring 2009. Our acquired goals are summarized by the following recommendations: to make computer science/computing science/informatics programs more attractive to women, to make curricula more engaging and interdisciplinary, and to make the public more aware of computer scientists' work. We address specific audiences with particular recommendations and feature 10 tips on how to publicize computer science via the media.

Introduction

Computer science (CS) (aka computing science or informatics) research develops rapidly; their successes impact economies as well as our daily lives tremendously. CS has become an important part of many other disciplines, including all sciences, social sciences, arts and engineering; a large part of research activities and jobs in CS are highly interdisciplinary.

From the 1960s until the early 2000s, CS has been popular: no extra mile had to be taken to attract more students to universities. While today our youth is using new technologies fluently, the number of CS students in university programs has declined alarmingly, both in North America and Europe. Further, the proportion of female undergraduate students in CS in the two continents is very low. This shocking trend of declining enrollment exists, despite a desperate need for more computer scientists in industry, and a popular debate discussing the issue in the media. Although the IT industry is booming and the job opportunities for CS graduates are excellent, the public perception appears to reflect a contrary attitude.

Dagstuhl Seminar Proceedings 09142
Perspectives Workshop: Preventing the Brainware Crisis
http://drops.dagstuhl.de/opus/volltexte/2011/3143

The participants of this perspectives workshop included researchers from academia and industry, teachers, and school administrators, as well as science journalists and employment officers. Participants were from five different countries and three different continents: North America, Australia and Europe. The umbrella topic of the workshop was "How to prevent the brainware crisis?" In other words, the workshop focused on how to turn around the decreasing number of computer science students in undergraduate university programs, and how to prevent a massive shortage of computer science researchers and IT professionals in the long run. The composition of the group enabled discussions on many different aspects regarding this challenge. However, despite the widespread of participants, the group was not as balanced as originally hoped for: several people from industry had to decline our invitation due to travel cuts in an economical difficult time. Our three-day workshop consisted of short presentations from experts introducing the topics, as well as of discussions and breakout groups.

In this manifesto we present three concrete recommendations, briefly summarized as: to make computer science programs more attractive to women, to make curricula more engaging and interdisciplinary, and to make the public more aware of computer scientists' work. We address specific audiences with particular recommendations and feature 10 tips on how to publicize computer science via the media.

Long Term Strategies for the Recruitment of Students to CS programs

At one of the workshop's general meetings we discussed possible definitions of CS. Reponses to the question "What is computing science?" identified this field of inquiry as a form of "meta-mathematics" that is interdisciplinary in application. This broad, engineering-focused definition was supplemented by descriptions of CS as a way of thinking that included logic, organization, computational thinking, structuring, modeling and creativity. It is abundantly clear that this vision of CS is not readily communicated to students in middle or secondary schools or even to university students in their first years of CS programs. Descriptions of the *pedagogy* of CS present a rather bleak picture: CS in schools—both secondary and early university—often seems disconnected from true CS content, is strongly teacher dependent, is often only optional (in particular in secondary schools) and is too narrow in a curricular focus.

Curriculum recommendations

The group charged with the task of considering long-term strategies for a curriculum reform in CS considered first the topics in K-12 school curricula as a possible strategy. The present focus on keyboarding and spreadsheet software needs to shift towards knowledge tools, interdisciplinary projects and (more) free exploration of topics related to CS. We recommend the following changes to the curriculum in schools:

1. A more interdisciplinary focus on CS that concentrates on re-conceptualizing school CS as a way of thinking, with some increased hands-on, practical applications. We commend the approach in Austria to capture student interest in ages 6-10 with their field and suggest other countries could benefit from their approach. We also advocate the integration of CS into other subject areas, such as biology, language arts, etc.

2. We reckon that more students would be interested in CS university programs and careers in CS if they had the opportunity to engage in CS applications in secondary schools. We advocate *specific* modules teaching the design, creation and application of CS. These modules should include a mix of specific training and free exploration of what the application can and might do. As a possible strategy we suggest courses that "float" in secondary school curricula: these courses are not designated to any particular grade but are open for students to take regardless of their grade level.

Long-term strategies

What long-term strategies will ensure a change to the better? We recognize that the practiced pedagogy of CS is one of the major barriers. As one workshop participant noted, "We should not have to rely on the genius of a few teachers, for students to experience an interdisciplinary approach!"

Curriculum reform in CS is inexorably linked to the expertise, knowledge, enthusiasm and vision of CS teachers, both in schools and universities. In short, curriculum reform is likely to fail without the long-term investment of knowledgeable, experienced teachers. It is therefore our belief that every successful long-term strategy is a sustained investment in the education of CS teachers.

We note that in the present school system, the goal to adopt a more interdisciplinary approach is compromised. Even the most innovative teachers face significant barriers when working to reform CS-curriculum, including: resistance of more traditional-subject bound teachers, lack of time and resources in their daily lives to plan and design new curriculum.

Despite these barriers, we maintain that investment in teacher education holds the most promise for a long-term renewal of CS in the school-system. While ambitious, we believe that this is a most promising long-term strategy in the field of CS, and the most effective way to address declining enrollments in CS.

Our recommendations reach out to all three of the participants' continents: North America, Australia and Europe. We recommend that

- Governments' Ministries of Education
    1. Emphasize the recruitment of K-12 CS teachers.
    2. Introduce CS as a core subject in schools (see our curriculum recommendations above).
    3. Develop CS in schools as a more "open-ended" course of study to enable teachers to customize courses for student aptitude and ability.

- School Systems
    4. Provide time and resources to enable teachers to develop content with interdisciplinary CS connections.
    5. Enable their CS teachers to develop on-line communities with teachers in other schools to encourage mutual support and the sharing of resources.

- University teacher education systems

    6. Ensure that CS teachers have sufficient background in computational thinking, graph theory, and recent developments in the field of CS.
    7. Engage in research towards finding sound pedagogical models and examples to teach CS effectively.

- Major IT corporations

    8. View teachers as a key resource for recruitment to their field.
    9. Be approached for investing in the development of CS teachers. For example, corporations could support the development of a model school to experiment with CS integration, teacher education, etc.

Young Students

Today, school (K-12) students have different knowledge, skills and interests than just a decade ago. They grow up using mouse, mobile phone and remote control ("homo zappiens"). Their learning is often game-based or influenced by playing computer games, and they may even create their own computer games. They typically participate in several online-chats at once, maybe even in different roles. They are used to multitasking, although they might not be able to do so efficiently. Some may have more knowledge about URLs than about capitals of countries. For many students, their school functions as a meeting point to communicate with friends instead of a location for learning.

"Teaching is simply like taking a horse to the water. The leader of the horse, however, cannot make the horse drink!" Instead of presenting the complete curriculum content, we recommend that teachers become facilitators, moderators, tutors or coaches to enable cooperative, open and self-responsible learning.

Important demands on

- Didactics
    1. Development of interdisciplinary themes that allow the integration of CS
    2. Keep off from fixed learning units to learning projects; learning objectives can be achieved in many ways and CS can find its place in here. The activities in *Computer Science Unplugged* may be a start.
    3. Plea for didactical diversity
    4. Development of didactical scenarios that include CS

- Teacher education
    1. Implementing the basics of CS/I in teacher education
    2. Development and deployment of professional, structured learning objects for information and communications technologies (ICT)
    3. An ICT-object consists of two parts–the information part and the scalable pedagogical part

- Schools
  1. Learning is mainly a social process; also foundational concepts in CS can be taught this way (see for example Ccsunplugged.org)
  2. Knowledge is generated through action and handling (see for example csunplugged.org)
  3. Education needs both: didactics and content

Extra Curricula CS Events

We propose to create an interactive annotated world map that is accessible on the Internet and allows every interested institution to enter their extra curricula CS events that are then displayed on the map. We anticipate that such a map fosters collaboration and enables wider assessment and evaluation techniques of the activities. Because there is an anticipated overlap in how institutions go about offering and evaluating curricular services, the map should allow for cross collaboration and data gathering tools. The map will support, simplify and improve the evaluation of particular activities and strategies as it can be utilized for large samples across multiple institutions.

Media

The lack of understanding of what computer scientists do results in a public view that describes our field with properties such as trivial or uninteresting. We recommend that every computer scientist make an effort to establish relationships with the media. Using some of the tips below may help. A complete version of our Media Group results can be found in "Reaching out to the Media: Become a Computer Science Ambassador" by Rosamond *et al.*, Communications of the ACM, March 2011.

Ten Tips to get your work into the media

1. *Use the "dissemination of results" requirements of your grant proposals.* This refers to CS researchers who, in grant proposal applications, are asked to convey they proposed research to the public. Recycle good ideas you already wrote up understandable!
2. *Find a hook:* If we do not have news for the science beat writer, our research is not going to get a mention. We need to clarify what is "new" about our work and why it is relevant to anyone outside our lab. Why should the public care about your work? The hook may be a vision of what your research is aiming for in the long term or the most important piece of advice in this article.
3. *Establish personal contacts.* Knowing a science journalist helps!
4. *Get started.* Starting small is fine!
5. *Use the enthusiasm of your students.* E.g., report about an outreach project like an afterschool club where the kids get excited about activities, such as computer science unplugged (csunplugged.org).
6. *Approach different types of media*, such as student magazines, cartoons, computer games (e.g., www.seriousgames.org), a computer corner in the children's page of the Sunday paper, music, social media like twitter, weblogs or YouTube, art, theatre, radio programs, novels, and even dance (see Scott Kim and his 'dancing for math', www.mathdance.org).
7. *Find role models or ambassadors for computer science.* E.g., a well-known author, scientist, sports figure, politician or even a wildly popular musician or entrepreneur who pleads for a better public understanding of computer science.

8. *Mention the foundational principles on which your clever insights are based.* The general public will become familiar with hearing the same fundamental concepts over and over (e.g., Halting Problem, computational complexity, algorithm, sorting, searching and so on) and become more techno-savvy, just as if they have unconsciously taken the course CS 101! Computer science basics can become common knowledge.
9. *Include writing assignments in your classes to help your students learn to communicate their ideas to the public.*
10. *Use links to other disciplines.* Computer science is used in disciplines from archaeology to zoology. Try for joint presentations where you can present the underlying computer science that is used in these other fields.

Development of Student Enrolment in IT programs in Germany

In the following we address two key questions:

- How did the demand for university programs in information technology evolve since 2000?
- How did the number of employed and unemployed university graduated professionals in the IT sector evolve since 2000?

To answer these questions, data mostly provided by the German Federal Statistical Office is used. For each year, the number of freshmen is based only on the enrolment numbers in the winter term; some are shown in Fig.1.

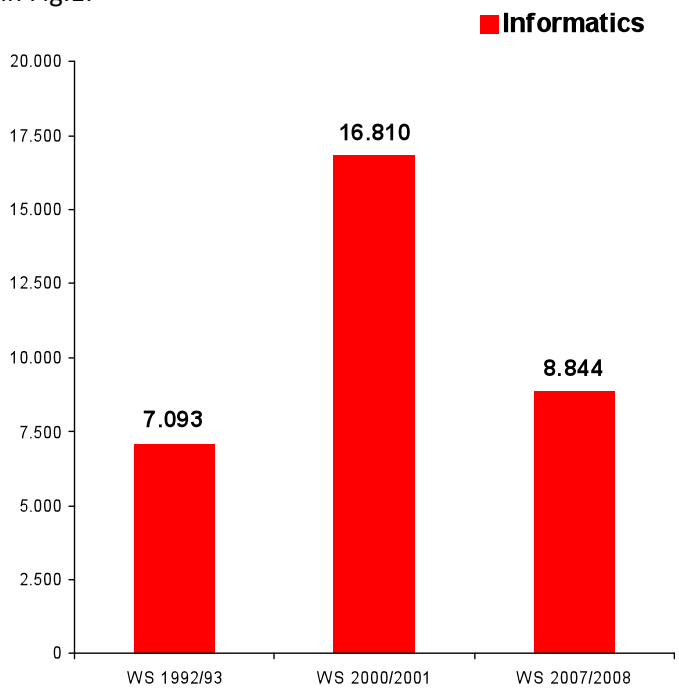

Fig. 1: German freshmen in Informatics

A first observation relates to the development of freshmen numbers: at first, numbers were increasing. Then, after the year of the "Dotcom-Crash" (2000), they strongly declined: 7.093 freshmen in 1992, 16.810 freshmen in 2000, and a decline to 8.844 freshmen in 2007.

Next, we analyze computer-science related university programs (cf. Fig. 2). In addition to the above-mentioned program, a CS university degree, there exist a number of related degree programs (in Europe, often with the term "informatics" as part of their name). We considered in particular:

- Health Informatics
- Media Informatics
- Computer Engineering
- Bioinformatics
- Business Informatics
- Information and Communication Technology

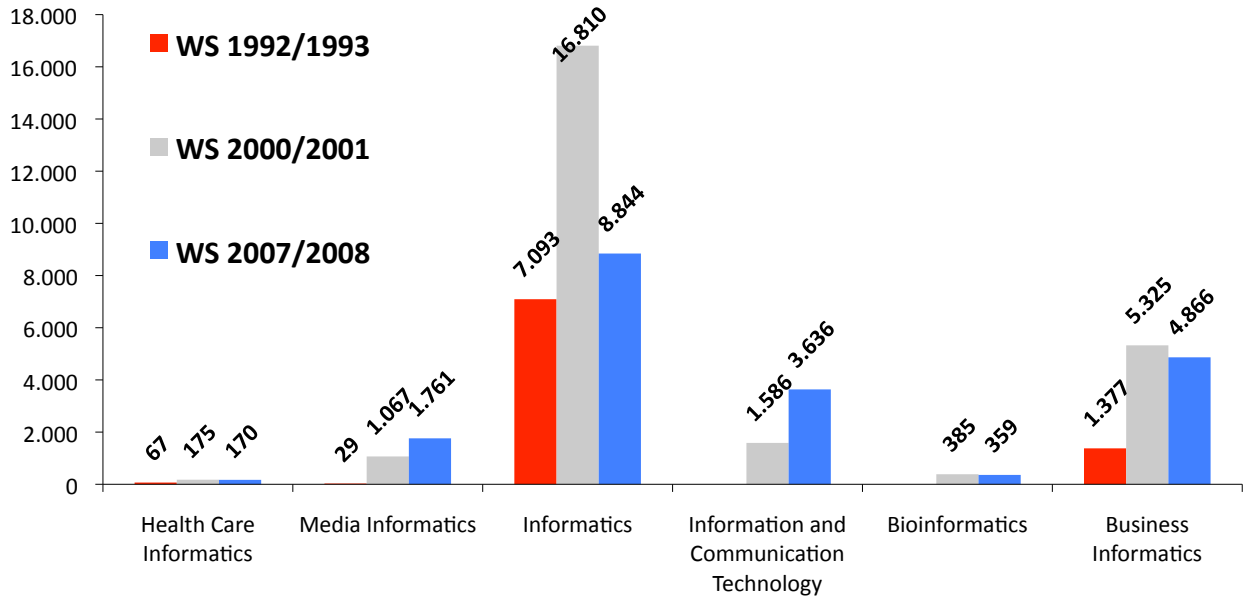

Fig. 2: Freshmen in CS related university programs

We observe that there is no uniform trend over all study programs:

- Continuous increase of enrolment (Media Informatics with 29 freshman in 1992, more than 1.067 in 2000 and over 1.761 in 2007)
- Stagnation of enrolment (Business Informatics with more than 1.300 freshman in 1992, in 2000 over 5.325 and in 2007 decrease to 4.866))
- Decline of enrolment (see also numbers above)

Adding up the enrolment numbers of all of these degree programs leads to an interesting result: the number of all freshmen developed positively beyond the year 2000:

- 64.609 freshmen in 1992
- 104.612 freshmen in 2000
- 122.063 freshmen in 2007

This served as a fundamental observation for further discussions in our workshop, as it implied that the decline of student numbers in CS programs does not necessarily mean that students are not interested in computer-science topics.

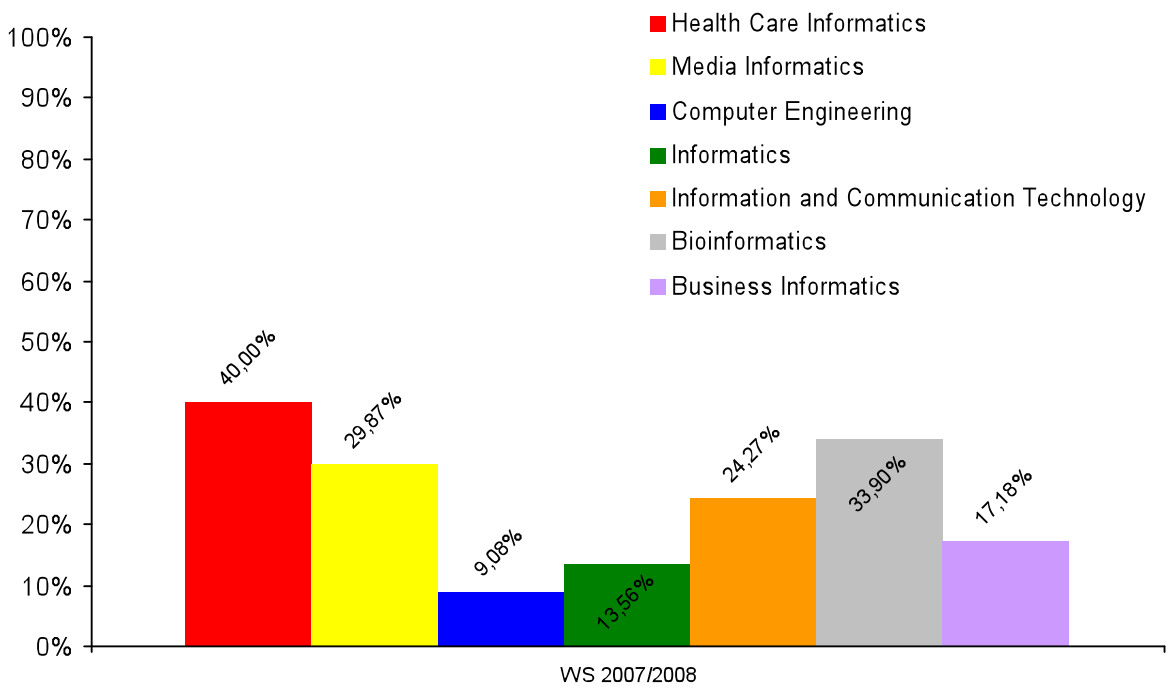

Fig. 3: Women as freshmen in CS related university programs

Another interesting observation is related to the percentage of women in the study program in Informatics (cf. Fig. 3). The results are:

- The percentage of women as freshmen in the study program Informatics is relatively low.
- Between 1992 and 2000 the percentage increased from 12,25 to 17,27.
- Between 2000 and 2007 the percentage dropped again to 13,56.

There is only one university degree program with an even lower percentage of women (Engineer Informatics with approx. 9%), but there are several with a considerably higher percentage of women (Health Informatics 40%, Media Informatics 29,87%, Bioinformatics 33,9% and Information Communication Technology 24,27%). This supports the hypothesis that women are interested in computer science, if what they learn is related to application domains like media, communication, biology or medicine. To increase the enrolment in CS, we suggest as potential promising approach to target women by stressing that computer science has practical implications.

Finally, we discussed the development of the employment marked for new IT graduates: on the one hand, the number of employed academic IT–professionals continuously increased from 145.063 in 2000 to 176.543 in 2007. On the other hand, the number of unemployed academic IT-professionals increased from 2000 to 2004 from 2.649 up to 15.663, but declined again to 6.845 in 2007. While this is a very low unemployment rate, it appears to be higher than in 2000, when industry actively was recruiting foreign IT-professionals.

Overall, the job market in the IT-sector is not just promising but, depending on our economies, we believe that there is actually some danger that there will be even serious lack of young academics in areas like computer science.

Recommendations for Funding Agencies and Industry

Many of the recommendations above depend strongly on funding. Today, many initiatives are based solely on volunteers.

- We ask both, funding agencies as well as industry, to not only fund research that focuses on technology, but also focuses on educational questions, such as: what curriculum and activities or what organizational changes in K-12 will encourage children to study CS or its related fields?
- We recommend that the dissemination of research results should include the general public in every age group (to produce a flyer and put it on the web is certainly not enough).
- While a number of universities is commendably active in the field of recruiting CS students (for example, via outreach to our youth) and while many developed and designed activities and programs for this purpose set out the objectives (1) to present a realistic picture of what CS is really like and (2) to counteract the widespread negative image of CS and computer scientists, hardly any research exists on how effective the different strategies are. We propose financial support to enable studies on the impact of these initiatives.
- We further encourage industry to support and sponsor activities like summer camps, computer science competitions.
- We urge both, funding agencies and Industry, to fund exhibitions on computer science topics in science museums.

Recommendations for LZI Schloss Dagstuhl

Research Seminars

Today, LZI Dagstuhl organizes many interdisciplinary research workshops in the areas such as Arts and CS, Biology and CS. However, research in Education and CS (CSE) is not on the list, although conferences such as SIGCSE (5000 participants) and ITiCSE are large and recognized. Therefore, we recommend to add CSE to the list of Dagstuhl topics and to conduct increased research seminars in the following areas.

- Education (including assessment and evaluation in education, education in K-12, education at the university level)
- Computation as a part of nature, part of other sciences, driver of other sciences
- Empirical methods for computer science (HCI, education, the human factor)
- Psychology + CS

After every seminar, a short YouTube (2-5 minutes) clip could be produced explaining the seminar's topic and its impact on science and society. These videos could then be hosted on Dagstuhl's own YouTube channel, which still is to be established.

Other Dagstuhl events

- Continue events like science journalism, networking with non-researchers,
- Schedule events in parallel to related seminars, e.g. science journalism in parallel to a important/communicable topic,
- Introduce a journalism fellowship at Dagstuhl or at your CS department: A journalist is allowed to stay with you for some weeks to have the opportunity to investigate your subject/project in deep,
- Provide grant-writing workshops.

And, finally, put the CS unplugged video on the LCD display at LZI Dagstuhl.

Some References

The interested reader may want to have a look at the following web pages, books, and articles.

- www.bebras.org: The international Bebras contest had about 160000 participants in 11 European countries in 2009.
- www.log-in-verlag.de: Some participants of the workshop contributed to a special issue on "illustrations - models and reality" of the German journal "LOG IN - Informatics education in schools", No. 160/161.
- communicatingscience.aaas.org Tools for Scientists and engineers for communicating science (from the American Association for the Advancement of Science).
- csunplugged.org: **Computer Science Unplugged** by T. Bell, I. Witten, M. Fellows. See Google and YouTube videos of unplugged activities. These materials and activities for communicating the mathematical ideas underlying computer science to young audiences are appropriate for any age group.
- G. Carrada, "Communicating Science: A Scientist's Survival Kit," a 75 page guide to successful communications published by the European Commission Directorate-General for Research, 2006. Available at *ec.europa.**eu**/research/**science**-society/**science**-**communication**/index_en.htm - 23k –*
- Dagstuhl Perspectives Workshop 09142, "Preventing the Brainware Crisis". See www.dagstuhl.de/09142.
- J.M. Wing, "Computational Thinking," CACM, viewpoint, vol. 49, no.3 March 2006, pp. 33-35. Chinese translation in *Communications of CCF*, vol. 3 no. 11, November 2007, pp. 83-85. French translation in *Bulletin of Specif*, translated by Pierre Lescanne, December 2008.
- **Don't Be Such a Scientist: Talking Substance in an Age of Style** (Paperback) by Randy Olson, Island Press, 2009