Meeting Usability Goals for Software Products

John L. Bennett
IBM Research Laboratory, San Jose

ABSTRACT

Making software products more usable has been stated as an industrial, national, and even international goal. Constructive exchanges between those working in universities to build theory and those working in industry to build products have been identified as one way to speed the achievement of this goal. Programs within IBM have encouraged such exchanges. A discussion of the nature of collaborative work suggests ways to facilitate interaction for mutual benefit despite possible differences in culture and purpose.

INTRODUCTION

I welcome this opportunity to address, within a theme of software ergonomics, some issues in product development that have long been of interest to me. My views are based on my personal observations during my 20 years working in an industrial research environment.

During my career in IBM I have had experience in design of user interfaces in library systems, decision support systems (1), and office systems (2). Most recently I have been working with an IBM development division to outline generic concepts and specific conventions needed to support a user-oriented evolution of the interface to products (3). In the first part of the paper I comment on some of the topics important when building human-computer interfaces - in particular, interfaces suitable for people who are professional in their interests and in their commitment to results but who are not computer professionals.

Making computers more usable appears as a commercial (e.g., 4), a national (e.g., 5) and even an international goal (e.g., 6). To achieve increased usability requires both technical innovation in product design and engineering excellence during product development. Thus, to make more usable products we need the skill of innovators who develop theory and abstract concepts (typically people working in universities). In addition we need the skill of innovators in industry who develop and apply engineering and management techniques based on practical experience.

In my informal work with colleagues from the university environment I have gained a deep respect for the role of theory in helping us to abstract from the concrete details of specific designs so that we can derive principles to be successfully taught to new generations of designers.

I see an opportunity for collaboration between people in universities and people constructing software products in industry. In the second part of the paper I suggest that such a collaboration requires that those involved overcome well-known differences in culture and purpose as they identify mutual benefit, establish trust, and become committed to achieving usability results. This is needed if the potential opportunities for the *impact of practice on theory* and the *impact of theory on practice.* are to be realized.

My personal observations and interpretation may not represent an IBM position or IBM policy.

LOOKING AT A PROBLEM

What is required to "meet usability goals for software products"? The purpose of this section is to suggest how development of theoretical concepts may be useful to support current and projected practical development work.

What Is Meant by Usability?

Shackel (7) summarizes the work of a number of authors as he gives definition to the concept of usability. For my purpose here I paraphrase Shackel: "usability is defined within a relationship among user, task to be carried out, product to be used, and the environment of use". For a PRODUCT to be claimed as usable it must enable some required percentage of the appropriate range of USERS to carry out some required percentage of the range of TASKS for some required range of usage ENVIRONMENTS. Usability can be measured in terms of the following "dimensions":

- ease of learning (time to learn to a criterion of performance),
- ease of use of a product once learned (time to accomplish representative tasks), and
- attitude toward continued interaction (willingness to use the product).

Thus, product function and usefulness are necessary, but not sufficient in themselves, to meet usability goals. The definition can be expanded to bring out other dimensions and more detail, but this is a starting point for determining measurable, testable criteria.

We note that all these measures or indicators of usability are related to *performance of the user* with the completed product. That is, they give no intermediate clues for predicting performance at the user interface short of building the product (or a reasonably faithful mockup) and testing it. Few theoretically-based surrogate measures are in current use for reliably estimating in advance how design decisions will affect user performance. Put another way, we do not yet have the kind of "design equations", based on a scientific foundation, that enable an electrical engineer to do rough calculations of circuit properties in advance of construction. Work such as that of Card, Moran, and Newell (8) is a step in this direction.

What Is Meant by Usability Goals?

For the usability "dimensions" suggested above, how can we go about setting the criterion values? For example, what are appropriate levels for "the required percentage" and the "range of tasks" necessary to be competitive?

For a product intended for introduction into a competitive marketplace, many of these parameters must be set in consultation with marketing people. In order to be useful during product development, usability goal statements and ways of measuring whether they are being met must be compatible with the tools that developers customarily use to manage resources. Typical parameters of interest to developers are *function* (what the product can do or can support people in doing), *cost* (how much money is spent during development), and *schedule* (the calendar time from beginning to end). Usability goals must take on similar tangible, trackable attributes if they are to be integrated into and be managed and met within the current practices found in the typical development cycle.

Empirical work based on theory can help define distinctions and relationships that can be used as estimators for final performance. For example, the "fastman, slowman" models of Card, Moran, and Newell (8) are a step toward calculations helpful in early evaluation of designs. Thomas (9), though recognizing the progress represented in the work, cautions us on the need for giving the system designer "an appreciation for the range and magnitude of effort that is really required to produce a system with good human factors; ... social and motivational issues can totally swamp the effects measured in (current) models."

Another area where theoretical constructs can be of value is the representation of usability goals in a form amenable to management. The work of Gilb (10) is directed to this end, and suggestions for how it could be used in development are given in Bennett (11). People trained in theory can also help with statistical sensitivity analysis (ranges for variables) and with design of experimental evaluations.

What is Meant by Software?

The definition of usability and the meaningful specification of usability goals clearly apply to the user's interface to the product as a whole, both hardware and software. While it is true that hardware is ultimately a limiting factor at the user interface, we have seen how creative design can achieve remarkably different levels of support through the same terminal device. A good example is the wide variety of interaction styles found on the IBM PC. Whether or not this wide variety is always supportive of user performance goals is another question, and the point here is merely to focus on this as an illustration of software flexibility.

The area of software engineering is one of particular importance for speeding improvements (measured in terms of user support) in the transfer of technical ideas from innovators in university environments to practitioners in industry. Indeed, a central goal of both the Alvey Program and of ESPRIT is to reduce the time lag by increasing the constructive interchange between the academic and the industrial community.

What is Meant by Products?

A product is an end result intended for the competitive marketplace. Products are ultimately validated through commercial acceptance, and this is influenced by many factors beyond usability or technical excellence. All of us have seen instances of products that were innovative, constructed to exacting quality criteria, and still not commercial successes.

We recognize that products emerge from a development process, typically considered to have several phases. A synthesized taxonomy, adapted from Bennett (12), suggests what is required at each step. By implication, this establishes a scope for work on usability issues.

1. Planning and Requirements - Stating objectives, recommending functions to be included, defining the intended user community, indicating how the new product will affect these users, and establishing meaningful, measurable, testable goals to guide allocation of resources for development. All this is done from a *marketing* perspective.
2. Design - Drawing on technology to shape the product concept, developing the conceptual model to be understood by the user, and establishing the design decisions intended to meet the requirements. Writing the functional specifications.
3. Development, Implementation - Managing the technology and resources needed to build the product, addressing user needs as trade-offs are made throughout the process. Implementing the functional specification.
4. Test and Evaluation - giving feedback to designers during development, during product assurance, and during field use as input for design of new products.
5. Selling the Product - helping persons see potential benefits from use.
6. Installation and Training (Operations) - helping users to cope with complexity during learning and use. Implementing maintenance procedures.

Until several years ago usability work in industry tended to focus on phase 4. Efficient laboratories, staffed by skilled human factors people, became justly well-known in IBM for testing keyboards and the quality of display images. Gradually the complexity of interacting with software, even for data processing professionals ("people who are paid to be inconvenienced"), became an important product consideration. In addition, the advent of the PC led to increasing marketplace importance of product usability for people who were not data processing professionals. To meet these needs emphasis has gradually shifted to more involvement in phases 1, 2, and 3. About the same time the concentration of human factors professionals shifted from hardware to software products, and young graduates from university programs in psychology and human factors were hired in increasing numbers.

Meister's (13) list of what human factors engineers need to know when working as team members on military systems also applies to product development in industry. While recognizing the need for the engineer to provide concrete, precise, and quantitative inputs, he also recognizes the lack of context-relevant data and the lack of time and resources within the development environment to do the research needed to gather the data. In a remark possibly intended for university researchers he suggests, "It is difficult for those unfamiliar with the development process to understand the gap between the conditions under which most research is conducted (control, precision, and time) and the high-pressure conditions in which the human engineer functions."

On the other hand, software people sometimes act as if those with human factors training are "gurus" with "all the answers", and as a result they expect miracles far beyond the state of the art. This is a real danger if it leads to a failure to follow an iterative design and testing process. Such an omission is a false economy and can lead to severe product problems. (9, 14).

Summary

Meeting usability goals for software products requires the skills of people with refined practical understanding and strong teamwork ability as development trade-offs are made. Anything that is perceived by developers to stand in the way of added function, to increase cost, or to cause schedules to slip is likely to be resisted. In this situation developers may consider some user needs intangible, may assume that investment in usability can be postponed, and may assume that users will "adapt" as needed. All this tends to make the work of the software ergonomist difficult. Theory-based methods proven in industry are needed to aid the human factors engineer.

A NEW CHALLENGE

I suspect that some of the same issues we have observed in the discussion of product development above will be relevant to the fulfillment of usability goals in the important new programs in Great Britain and on the European continent.

On a national scale the Alvey Program, seen as "Britain's answer to Japan's fifth generation project" (5), has funding plans for projects in Very Large Scale Integration (VLSI), Expert Systems, Software Engineering, and Man-Machine Interfaces (MMI). The purpose in MMI projects is to "raise the level of research and improve the quality of products through better MMI technology and design" (15). An estimated 450 human interface researchers are working in over 100 companies with products related to information technologies (IT), but little organizational focus is observed. The various research groups in university communities have few opportunities for interdisciplinary work and few coordination mechanisms to avoid duplication of work. Alvey intends to provide an opportunity for consortia and for a "market-oriented approach in view of the application-sensitive nature of MMI work and to provide researchers with a focus for their work and a means of validating its applicability".

This approach is viewed by some with misgivings. Since the Alvey Directorate now controls over half the funds available for computer science research in Britain (5), there is some concern among academics that they will be forced by economic considerations into industrial research with commercial partners at the expense of longer term fundamental research. Much is said to depend on how well the partners work together.

On an international scale, the European Community through ESPRIT (European Strategic Program for Research and Development in Information Technology) has initiated programs in Micro-Electronics, Software Technology, Advanced Information Processing, Office Systems, and Computer Integrated Manufacturing (16). The objective is to promote pre-competitive and generic research and development in IT through collaborative academic and industrial projects. Reporters have observed, "European industry is experiencing great problems in bridging the gap between innovation and the introduction of new technologies". The 1985 ESPRIT response has been to approve 104 projects funded by $130 million from the Community and by matching amounts from contributing organizations. The projects include 344 participating groups from industry, 107 from universities, and 97 from research institutes. Human factors topics are included in the Office Systems area, where over 20 projects are funded for 1985. The emphasis is on cooperation and joint work to provide advantages unavailable to projects working independently.

The press has noted (17) the difficulties of coordinating work over distances, coping with differences in national languages, and accommodating differences in cultural outlook found in industrial and academic institutions. "Relations between private companies and leading research universities, an increasingly important factor in the U.S., remain very poor in Europe despite the step forward that ESPRIT represents."

In individual industrial firms, national programs, and international communities we see identified the need for interaction between people in university and industrial environments. The opportunity is for the study of practice to inform theory and for theory to guide practice.

REPRESENTATIVE PROGRAMS IN IBM

In this section I point out some of the programs that encourage interaction between human factors specialists in IBM and professionals in universities. Some of the approaches may, with proper adaptation, prove useful in Europe.

Student Temporary Employment

Several programs have been created to enable students while still in the university to sample the kind of work done by human factors professionals in industry. Generally the temporary appointments are for one year (possibly renewable) and are offered to people who have completed at least one year of graduate study. The students, often enrolled at a school in the geographic vicinity, work half time during the academic year and full time during the summer. Some locations have arrangements for cooperative work-study programs where students come from a distance and work at IBM for at least 6 months during alternate semesters. A benefit to universities is that this financial support for students conserves the limited funds available for research assistants, allowing some expansion in the number of students in graduate programs.

Managers ensure that the student is directly involved as part of a project team, helping to get a higher quality product into the field within the constraints of the product development process. Often managers will encourage the person to become co-author of a professional paper which can be submitted for publication or presentation at a conference.

The presence of freshly trained, energetic, and eager-to-prove-themselves people actively committed to human factors goals is valuable to industry. The problem-oriented, solution-driven nature of the work within the context of the phased product development is often an exhilarating experience for students. The talents the students bring can be especially important for software topics, as the new skills complement the senior judgement of the established staff members who were often trained some years ago in more traditional ergonomic subject matter. Temporary students can be particularly valuable if they have courses in both human factors and in computer science.

But we should not be mislead into thinking that all the work has the pace or excitement found in a television dramatization. Much of the real progress in improved software ergonomics for products comes through persistence and determination in the face of "realistic" function, cost, and schedule constraints found in product development. Achieving the needed result requires persons with a vision of the larger, longer-term possibilities, willing to develop skills as negotiators, who can accept short-term, sub-optimal usability compromises forced by current resource (time, money) restrictions. The theme reports at Interact'84 (12) hint at some of the frustrations as well as listing the accomplishments.

Post Doctoral and Visiting Faculty Programs

A second type of program, available at some locations, attracts post-doctoral students and visiting faculty. These temporary positions, held for at least six months and more commonly for a year, are open to more seasoned persons who may contribute to several projects in addition to focusing on achieving a tangible result for a particular project. Sometimes negotiated project assignments are needed to ensure that some non-proprietary part of the work can be described for publication, as that is usually particularly important for visitors in this category.

The opportunity for each person involved is similar to that for temporary students. The post-doc can see if the kind of applied work is of continuing personal interest. The faculty member can gain or renew an experience of how theory could guide practice and can see first-hand where theory development would be of particular value in the industrial work observed. This tends to have beneficial effect in keeping the curriculum current, and it assists the professor in counseling students upon the return to the university.

Shared University Research

IBM has several kinds of contracts with academic institutions. One activity of particular interest for IBM-university interaction is the Shared University Research (SUR) Program. The purpose of SUR is to open an additional avenue for scientific innovation to come into IBM and to foster university understanding of current problems of interest to industry. The "shared" refers to the fact that funds are drawn from an IBM Headquarters budget and from "technical sponsors" at development locations. This balance leads to a long range focus and at the same time ensures that some group in IBM has an interest in using the technical outcome of the research. The results are also "shared" in that the objective of each research program is intended to be broad enough to be of interest to more than one development location.

The formal program, first initiated in 1980, has grown to about 200 current contracts established with over 100 different universities. About half a dozen current contracts have a human factors focus. The program has been international in scope, as one of the current contracts is between IBM Kingston and the Technical University of Vienna. This particular project "makes it possible for two institutes to increase the cooperation between the human engineering and informatics disciplines and to give students opportunities for dealing with future-oriented problems" (Prof. Wojda, Prof. Kerner, press release, May 1985).

SUR contracts cover university overhead expenses, and all work must be explicitly non-confidential. The principal investigators are therefore urged to enlist and fund graduate students in carrying out the work, and they are free to publish research results in professional journals. IBM SUR sponsorship is arranged a year at a time, and it is renewable by mutual agreement for up to three years. After that time, it is assumed that the value of a particular project will be established and that any continuing work will be funded entirely by a development division.

Each research proposal, sponsored by a development location, is reviewed within IBM by one of several SUR advisory councils, each one covering a technical area. Once a contract is initiated, the council monitors progress by periodic reviews. Participation in a review process is itself a valuable form of university-industry interaction. The questions and comments help the academic researchers emphasize those aspects of the research of interest to industry. Reviewers can see how work based on theory and science can be generalized beyond specific techniques used in research experimentation.

As would be expected in any sponsored research, IBM sets the objectives for results. However, the university researchers select the particular technical approach. Interaction with the sponsor during SUR negotiation and reporting does offer an opportunity for the researchers to choose specific project content that is of mutual interest. This selection process can help researchers set up a program which is both scientifically valid and of interest to industry. In this way researchers can find outside funding for generic work they might undertake in any event. Other university funding may be used for work of equally high scientific quality but with less obvious immediate industrial relevance

The SUR-sponsored work of Kieras and Polson on "cognitive complexity" may be of particular interest to this conference. Several publications (e.g., 18) have documented the scientific aspects of this work, which are extensions of the results of Card, Moran and Newell (8) at Xerox. The theory suggests a scientific approach of potential benefit to all users, regardless of the fact that the editor used as a model in the study was particular to IBM. This kind of evolution in scientific results can take place in SUR without getting into questions of marketplace competition. This is a particularly important aspect of university and industrial collaboration.

Consultants

SUR contracts for non-confidential work are made through a university. In contrast, university professors can be engaged as individuals to do specific consulting work that may well be confidential. The industrial firm expects to obtain a particular result, and the professor gets a close look at an issue of interest to the firm.

As an example, Kieras and Polson are working with the IBM Research Division as consultants to explore extension of "cognitive complexity" theory to processes more complex than text editing (e.g., description of user's how-to-do-it knowledge in document formatting tasks). This particular project is not confidential. The research staff can help work out development and application of the theory in a diagnostic mode with less time pressure than found in a product development group. The university researchers are able to extend the model earlier than otherwise would have been possible using only the resources available in the academic environment.

IBM Visitors at Universities

A number of IBM staff members are routinely invited to give talks at universities. In addition, depending on local conditions and individual initiative, some human factors professionals have become lecturers and adjunct professors. In this capacity they are alert to design of course curricula that prepare students for productivity in industrial work without decreasing the training in fundamentals that is also needed. Finally, IBM has an extensive program of internal IBM and university sabbaticals for professionals in all disciplines. All these activities serve as ways for people in industry to make issues of interest to them known in universities.

Summary

I have only mentioned programs where I know of constructive personal interaction between IBM software ergonomics people and university staff over an extended time.

These include temporary on-site employment of students and staff, off-site research, on-site consulting by university staff, and IBM visitors to universities. I have not included consortia between groups of industrial partners and groups of universities, nor have I described IBM corporate grant programs to individual universities. These activities lead to personal interactions, but the primary base is institutional. Finally, I have taken for granted the continuing professional exchange between recent graduates and their university mentors, industry and university professional discussions at conferences, and attendance at courses. These continue to be important in the flow of ideas between communities.

OVERCOMING BARRIERS TO COLLABORATION

The success of these programs in fostering increased interaction has been achieved despite well-known differences between industry and universities. The exchange of letters in recent issues of the Human Factors Society Bulletin offers a good illustration of deep-seated division even in the relatively egalitarian U.S. community. Meister (19) believes that behavioral research "does not adequately support those of us who 'practice' human factors (hf) in the real world". He comments on a "self-imposed technical segregation," observing that the worlds of the researcher and practitioner rarely interact. He suspects "there can be no research relevance to system development problems unless that relevance is intended before the study is performed." The result is that "the practitioner's effectiveness in applying human factors principles continues to depend largely upon his own experience and intuition. Kantowitz (20) rejoins that "the best practical tool is a good theory", suggests that practical problems have been solved by the application of theory, urges professors to train students to search for relevance in theory, and urges that hf specialists become "equally at home discussing theory or practice".

Such deeply held differences in outlook, quite common in my experience, are present in day to day work. For example, the researcher building theory does carefully controlled experiments to test a hypothesis or to validate a generic concept. The practitioner building a product runs pragmatic experiments intended to support a practical discovery process in a specific situation. If people with each perspective look only at surface purpose and action, collaboration will continue to be difficult. If we instead view the two activities as complementary and as leading to results needed to meet usability goals, then we can establish an extended basis for mutually beneficial work.

I suspect misunderstandings also have roots in different cultural values. Academic professionals have attained position, stature, and recognition through years of study and scientifically structured experimentation. Sometimes they view human factors professionals in industry as mere technicians, subject to the vagaries of product success in a fickle marketplace and making no contribution to knowledge that will last beyond the next product release. On the other hand, industrial professionals have earned respected positions on the development team by demonstrating resourcefulness and insight needed to achieve results despite product development constraints. Sometimes they view university professors as skilled in designing experiments to tease out statistically significant results of no interest to anyone outside the world of fellow academicians. Such contrasting viewpoints (put rather extremely!) would seem to make collaboration impossible.

Another possible barrier to collaboration, especially if work is funded by sources outside the university community, is the university concern about academic freedom - the pursuit of knowledge without interference by special interests. However, university administrators in the U.S. have become adept at keeping an appropriate distance between funders and researchers, and I do not see any insurmountable difficulty in establishing a basis for collaboration.

I mention these points to acknowledge that the differences in training, cultural values, and skills of those in the research and in the engineering communities are real. But I believe that effective collaboration can be achieved nonetheless.

I recommend for your consideration the insightful questions asked by Flores and Bell (21) about the nature of work, the role of trust and commitment, and the need to establish "conditions of satisfaction" in coordinated work. Though my prime focus here is on what the theory suggests about a basis for collaboration, those attending this conference may be interested in Winograd's description (22) of a tool that is being implemented to support "the language of work" in a computer network.

Flores and Bell assert that managers are paid to discover what is missing in the work that is already going forward and to bring that (which is needed and missing) into being. I maintain that all of us as professionals are (at the least) managers of resources. To paraphrase Flores and Bell, "Something begins to happen when we pose questions and then, as appropriate, give instructions, commands, and requests to the people who work with us in the context of our mutual commitments". This emphasizes the role of language, commitment, and networks in holding "conversations for action" to achieve mutually agreed upon results.

Thus, to summarize, Flores and Bell identify an opportunity for us to see ourselves as "human beings making linguistic commitments, soliciting commitments from others, creating and identifying possibilities, and dealing with breakdowns in the midst of a network of help." Indeed, the challenge of the Alvey Program and ESPRIT might be considered as "how to bring forth through language commitments to future actions".

In my work within IBM I have seen many opportunities for misunderstanding, disagreement, and unworkability arising from the kind of cultural differences identified by Meister and Kantowitz. I have observed that one person in such a conversation can often play a pivotal role in asking participants (including one's self) about intention. If, given a difference of opinion, people focus on the requests and promises made and the conditions of mutual satisfaction, this can be a powerful way of shifting from a context of "us" versus "them" to a focus on the common ground - the results to which those in the group are committed. This does depend on the degree of good will and trust that has been established in advance.

RECOMMENDATIONS

The Alvey and ESPRIT programs provide an external incentive for increased collaboration between university and industrial projects, a collaboration that is intended to achieve improved software ergonomics. I have no personal knowledge of the climate for cooperation that currently exists in Europe, so I can not make specific observations on the opportunities that you can create. However, if you do choose as individuals working within your organizations to create opportunities along the lines I have discussed, I can make some recommendations.

- Explicitly state and explore goals of individuals in order to establish mutual understanding, potential mutual benefit.
- Establish through your conscious intention and your resulting use of language the trust and openness that gives people permission to make mistakes and for all to learn from such mistakes. This allows the inevitable breakdowns, errors, and problems to be an opportunity for advancing the work rather than an excuse to stop it.
- Be open to the possibility that a member of the team (perhaps you!) can act for the moment as a disinterested third party to observe linguistic (cultural) misunderstanding and feed back to speakers what was heard. This gives the

team an opportunity to be sure that what was heard was what was intended by both speakers and listeners.

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