Evaluating Informational Tool Building and Utilization as Applied Research

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ABSTRACT

The advances of technology have altered the research theater and compelled information scientists to develop appropriate criteria for evaluating contemporary research. While classical scientists may not embrace these new research paradigms, they eagerly seek the tools created by information scientists that often enable and extend research to levels not otherwise possible. Informational tools include a broad range of hardware, software, survey instruments and other methodologies which are the object of research or are created to enable research in information and other sciences. The process of building and using informational tools has been presented to the scientific community as valid research in its own right. Rapid technological growth and societal demands for fast solutions to important problems require a progressive view of research and the establishment of criteria by which all scientists will recognize, support, and fund research in informational tools. This paper reviews the role of information science as a creator and user of informational tools. It attempts to rationalize the process of informational tool building and utilization in relation to the strict criteria of the scientific method. Using a model developed for artificial intelligence, criteria are suggested for evaluating applied research in informational tool building and utilization.

Keywords: information science research, informational tools, information science curriculum, applied research.

1. INTRODUCTION

The modern quest to create the intelligent machine began in earnest with the famous 1956 Dartmouth University Conference. Armed with third generation computer technology, a small group of men with a wide range of academic interests gave birth to a brash hypothesis: every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. Untethered with past prejudices or a structured plan, researchers left the conference like seeds scattered to the wind, free to grow ideas limited only by their imagination and ambition. The science of artificial intelligence (AI) was born.

After four decades, AI has achieved unquestionable status as a multidisciplinary science although it continues to embody an inexact form of computation. Despite its success, the nature of AI research remains at odds with classical scientific methods. In 1988, Cohen and Howe addressed this issue, postulating that the unique science of AI requires appropriate and relevant guidelines for conducting research [Cohen and Howe, 1988]. They offered new criteria for evaluating the AI research. These criteria were unique in that they attempted to bridge between classic science and the unique aspects of AI research.

Like AI, progress in information science is highly dependent on the development of advanced tools which reduce theory to practice, enabling and extending the limits of research. How does the process of tool building and utilization relate to the strict criteria of the scientific method? Information scientists certainly know what criteria are important in evaluating work within their field. But in order to gain legitimacy, tool building and utilization must establish criteria acceptable to the scientific community. This effort is essential in order to increase support for research in information science. The reality is that funding under the computer and information science banner most often goes to computer science.

This paper begins with the idea that research is a continuum extending from basic to applied science. The role of informational tool building and utilization is examined in several contemporary sciences. Using

Cohen and Howe's five-phase model, criteria are suggested for evaluating applied research in informational tools.

2. GRADUATE STUDIES IN INFORMATION SCIENCES

A working definition of information science includes several concepts:

> *the information science discipline centers on the development of systems and informational tools that improve the performance of people in organizations. Information systems and tools are vital to problem identification, analysis, and decision making at all levels of management. Information science professionals must analyze the evolving role of informational and organizational processes. Their work includes the design, implementation and maintenance of the information systems and tools that improve an organization's competitive position in a rapidly changing global economy.*

The graduate researcher pursues new theories or attempts to extend the existing body of knowledge. The thesis or dissertation must be an original research and/or creative project demonstrating the student's ability to 1) select a problem that can be studied in terms of time, equipment needs and experimental population available to the faculty sponsor, 2) search the literature, 3) organize and analyze the information that is available using logical and/or statistical analysis, and 4) present the results orally and in written form to the satisfaction of the faculty thesis/dissertation committee and the Graduate Faculty. Applied research in informational tool building and utilization can satisfy these requirements if accomplished within the bounds of acceptable criteria.

The scientific method addresses a specified problem, stating a hypothesis to be accepted or rejected through a process of controlled data gathering and analysis. According to Tuckman, the scientific method is [Tuckman, 1978]:

- *Systematic*. Problem solving is accomplished via identification of variables followed by research that tests the relationship among the variables. Collected data related to the variables allow for evaluation of the problem and hypothesis.
- *Logical*. The procedures used in the research process allow other researchers to evaluate the conclusions.
- *Empirical*. The conclusions are based on collected data.
- *Reductive*. Researchers gather data and attempt to establish more general relationships.
- *Replicable*. The research process is recorded and others may repeat the research or design future research based on the results.

Four major categories of scientific activity may be undertaken within this framework as shown Figure 1 [Thomas and Nelson, 1990]:

analytical	historical	philosophical
		literature review
		meta-analysis
descriptive	survey	questionnaire
		interview
		normative survey
	case study	
	job analysis	
	document analysis	
	developmental	
	correlation	
experimental	predesigns	true designs
		quasi designs
qualitative	interpretive	ethnographic
		participant-observer
		case study

Figure 1. Classification of Research Activities.

This model defines a broad range of research activities some of which may not appeal to classical science. Graphical user interfaces, data gathering programs, analysis programs, survey tools, simulation, models and other systems and methodologies comprise the range of informational tools that may developed or employed within this model. From another perspective, the work of science spans a continuum extending from basic to applied research as shown in Figure 2 [Hoenes and Chissom, 1975]:

Basic Research -----------------------	**Applied Research**
deals with theoretical issues	answers immediate problems
animal subjects	human subjects
laboratories	real-world settings
carefully controlled	lacks control
results lack immediate application	results directly useful

Figure 2. Fundamental Characteristics of Basic and Applied Research.

While these models provide a reference for scientists, it is reasonable to expect that creative and relevant methodologies may be essential prerequisites to new areas of scientific endeavor. For example, early researchers could not anticipate that technology would dramatically alter the research landscape by providing the opportunity for innovative endeavors in computational and informational tools.

3. APPLI ED RESEARCH IN OTHER SCIENCES

New sciences often develop controversial research models leading to intense debate as to the validity of the often self-proclaimed science. They gain respectability by developing a recognized body of knowledge. Three disciplines offering insight into the role of tools in research are geographical information systems, artificial intelligence, and health care.

Geographical Information Systems

The advancement of technology has incited an ongoing debate as to what constitutes science in geographical information systems (GIS). To some, GIS is viewed as a science which unifies the field of geography; to others it is dismissed as non-intellectual expertise. In an interesting article , GIS researchers explore the illusive nature of science [Wright, Goodchild and Proctor, 1997]:

- There are probably as many viewpoints about science as there are scientists and not all of them are necessarily correct.
- A concise definition of science is not possible in light of wide range of fields that differ from each other in philosophy, knowledge content and methodology.
- The term "science" may be defined as a logical and systematic approach to problems that seek generalizable answers.
- Science matters because it is held in high regard, and its very name ensures it a place in academia along with the perquisite funding and prestige.
- Science is synonymous with research which is synonymous with academic legitimacy.

The authors categorize GIS in pragmatic terms:

GIS as a Tool. This position incorporates the use of hardware and software to advance a specific purpose within GIS. The tool is neutral. It's development is driven by the application. The tool may not be mentioned when reporting the results of the research. The tool may have been developed separate from the research in which it is used.

*GIS as Toolmaking***.** GIS toolmaking is an academic effort to advance the tool's capabilities and ease of use. Toolmakers are researchers who "are likely to promote the adoption of GIS, play a role in educating users, and work to ensure its responsible use." The toolmaker must be schooled in both the domain and the toolmaking. The geographer often collaborates with toolmakers from the other disciplines. The tool is inseparable from the research problem, that is, research success is predicated on the successful invention and application of the tool. Tools are often developed by private industry to meet a need in the marketplace, however, tools are also developed in the academic environment when there is an immediate need, when the research is proprietary, or when there simply is no economic incentive to develop a "one-of-a-kind" tool.

*GIS as Science***.** This activity centers on researching basic sets of problems which existed prior to the invention of GIS, but are now more pressing because of the availability of new technology. The authors make a relevant point:

> *This practice of collecting sets of basic problems under new names has a long history in science. It occurred, for example, with the emergence of computer science, when the development of computing technology provided the impetus for solving certain fundamental research problems that had been associated with mathematics.*

From the GIS perspective, the IS researcher is a collaborator in the design and development of computer-based tools which enable research. GIS is the domain and IS is the implementor. GIS reports the research results, including the role of the tool. IS reports the methodology employed in building, testing and using the tool.

Artificial Intelligence

The history of artificial intelligence is remarkable in that so many disconnected researchers could discover common underlying theories applicable to a wide range of sciences. More important, AI has given all scientists a new perspective on the role and purpose of research. AI techniques have been used to build intelligent tools which advance applied research in many disciplines, performing a host of functional tasks including interpretation, prediction, diagnosis, design, planning, monitoring, debugging, repair, instruction, and control. [Mishkoff, 1985]. Given the *raison d'etre* of AI, it is not surprising that a redefinition of research was necessary in the late 1980s. The following quote from Cohen and Howe has been formatted by this author to emphasize their point [Cohen and Howe, 1988]:

> *Indeed, some of the most informative observations are* ***not*** *performance measures but, rather, describe: why we are doing the research,*
> *why our tasks are particularly illustrative,*
> *why our views and methods are a step forward,*
> *how completely they are implemented by our programs,*
> *how these programs work,*
> *whether their performance is likely to increase or has reached a limit (and why), and what problems we encounter at each stage of our research.*
>
> *To the research community, these observations are more important than performance measures because they tell us how research should proceed.*

This statement is a cornerstone of the argument presented in this paper. It captures the essential purpose of applied research in contemporary science, namely, to pursue every avenue leading to a better understanding of alternative solutions to a host of theoretical and real-world problems.

Health Care

The National Institutes of Health (NIH) commissioned The Working Group on Biomedical Computing, a group of researchers representing a broad range of medical and biomedical sciences, to study the convergence of biomedicine and computation [National Institutes of Health, 1999]. The committee recognized that the progress and level of health care is inextricably linked to research and development of informational and computational tools. They recommended the formation of National Programs of Excellence in several areas of medical computation:

> *With National Programs of Excellence bringing together interdisciplinary teams, researchers will be able to harness the power of tomorrow's computers by collaborating to develop mathematical models, write software, and adapt systems. Team members can cooperate on algorithm development, software development, database development, and system development. They can make computers useful research tools....*

The committee recommended funding of research for those who are inventing, refining, and applying the tools of biomedical computing. The NIH clearly recognizes that rapid technological growth and societal demands for fast solutions to important health related problems require a progressive view of research and the establishment of criteria by which all scientists will recognize, support, and fund research in tool building. This recognition must be expanded to support applied research in informational tools which improve clinician productivity and patient care.

4. INFORMATION SYSTEMS RESEARCH

In the mid 1980s, the Harvard Business School's Management Information Systems group presented a series of colloquiums on management information systems (MIS) as a field of study. The colloquium participants discussed major areas of IS research including basic research models, laboratory versus real-world experiments, and decision support studies. In the lead paper, the assertion is made that experimentation must lead to knowledge dimensioned in richness of world reality and tightness of control [Mason and Cox, 1989]. These two dimensions define a continuum between applied research (reality) and basic research (control). At the time of the colloquium, IS research was undertaken primarily in a laboratory environment; Locke argued that these studies were artificial and difficult to generalize to the real world [Locke, 1986]. Benbasat suggested that laboratory problems dealt with objective measures which may not be as important in field studies where measuring constructs may be more central to the research [Benbasat, 1989]. He posed interesting questions: Should theory and tight controls be relaxed in experimentation? Should exploratory experiments be encouraged which observe what might take place when studying new techniques? Is the trial-and-error method appropriate for scientific discovery?

This soul searching arose out of the fact that MIS research was not acceptable to the scientific community nor relevant to practitioners. Little empirical work was being done in MIS at that time and the work that was reported produced inconsistent results. This is the crux of the issue for information scientists.

Westfall recently examined the relevance of IS research, offering three scenarios of how the IS field might develop in the next decade [Westfall, 1999]. These scenarios range from optimistic to pessimistic views in which the role of IS education and research is strengthened or diminished. He noted that the strongest opposition to today's IS research comes from IS practitioners who are hesitant to support research which does not produce immediate answers to practical problems. This opposition, says Westfall, may not be relevant; the focus of IS research should be on the needs of IS students, employers, and society. IS researchers should pursue topics that are adaptive to the needs of IS research consumers. In addition, researchers should address unsolved problems with little commercial advantage. Despite the current lack of interest, IS researchers should seek an early involvement with practitioners in substantive projects to gain a mutual understanding of each other's objectives and to generate possible financial support.

Westfall notes that the best scenario for IS educators can only be achieved through vigorous efforts, that is, taking strong initiatives to meet the needs of students, researchers, and practitioners. This paper advocates one initiative: the establishment of criteria for evaluating applied research in informational tool building and utilization at the IS graduate level. Through these criteria, the academic, scientific, and industrial communities can build a relevant metric to evaluate IS research efforts.

5. CRITERIA FOR IS APPLIED RESEARCH

IS applied research is undertaken within the context of the competitive forces model wherein organizations strive to achieve a strategic advantage over competition through the effective design and use of information systems. Informational tools include any combination of hardware, software, systems, survey instruments and methodologies which are the object of the research or are created to enable research. Tools include software applications, database tools (rapid data capture, retrieval, and analysis), decision support tools (data warehousing/mining), user interfaces (human computer interaction studies, voice recognition), modeling and simulation, and, survey and predictive instruments (possibly web-based) created to measure specific phenomenon.

The following sections suggest criteria for evaluating applied IS research in tool building and utilization based on Cohen and Howe's five-phase model of the research process: 1) the research problem, 2) the tools, 3) the implementation, 4) the experiment's design, and 5) the results. Note that this model is most appropriate for small research projects. As with Cohen and Howe, a series of questions are considered by which researchers can justify their work to the scientific community. Because the goal is to validate applied research in informational tools, these criteria, adapted from classical science, will be familiar to the reader.

Phase 1. Criteria for Evaluating the Research Problem

The criteria for phase 1 are presented in Figure 3. Cohen and Howe refer to this iterative process as refining the topic to a task. This is perhaps the most challenging and creative part of the effort. Researchers consider what they want to do, why they want to do it, and alternative methods for doing it. The role of informational tools is defined and developed. These activities alone have important scientific value because they provide researchers with valuable insight to the process of selecting and defining research activities.

An important goal of the criteria is to provide early focus for the researcher in order to ensure that success or failure can be demonstrated. If the confidence level is low in the early stages of research, it may be increased by modifying the role of the tool. Potential problems arise when researchers attempt to reduce risk of failure by tailoring the problem to a narrow domain. This does not imply that the investigation of narrow-domain problems is trivial, but recognizes that good research is challenging and opportunities can be lost by the over-cautious researcher.

Does the research address a definable class or sub-class of problems?

What tools or class of tools are appropriate for this research?

What is the relationship between the tool and the research task?

Does the research create or improve a tool which supports other research?

Will the tool limit or expand the scope of the research?

Will the research contribute to the body of knowledge?

Is the problem domain too broad?

Is the problem a subset of a more general class of problem?

In attempting to narrow the problem domain, has the problem become over-simplified?

Are the goals of the research defined well enough to demonstrate a level of success or failure after the research is completed?

Does the process of building and evaluating the tool alone justify this work?

Figure 3. Criteria for Evaluating Phase 1: The Research Problem.

During this phase, the researcher is directed to the body of knowledge which certainly grows over time. A comprehensive understanding of this body may lead to strengthening of research goals and raise the level of confidence. In addition, the body of knowledge may lend insight to a general class of problems related to the current research.

Phase 2. Criteria for Evaluating the Research Tools.

The criteria for phase 2, presented in Figure 4, address the informational tool(s) as the construct used by the researcher to solve the problem. The tool may simply implement an algorithm or a more complex information system. Software tools are often inextricably tied to the problem and may adversely abstract the problem or limit the dynamics of the research.

Is there a clear relationship between the research problem and the tool?

Is the tool known in the field?

If not, is the tool an improvement?

Can the improvements be demonstrated?

Are there accepted metrics for evaluating the tool?

What assumptions are associated with the tool?

What limitations are associated with the tool?

How robust is the tool for noisy input conditions?

Figure 4. Criteria for Evaluating Phase 2: The Research Methods.

Understanding previous work is important if the researcher is to avoid reinventing the wheel (especially one proven not to work) and, if we have formulated a new method, there must be a way to justify that it is better than existing methods. Assumptions and limitations of the method provide the boundaries that will characterize the results. In fact, tools may be evaluated solely in terms of the validity of the initial assumptions and limitations.

Phase 3. Criteria for Evaluating the Tool Implementation

During the implementation stage, tools to support the experiments are built and evaluated. The criteria for phase 3, presented in Figure 5, may be used to evaluate the tool apart from the research in which it is employed.

Does the tool implementation reflect the method?

Can external behavior and internal behavior of the tool be evaluated?

Does the tool implementation demonstrate a new capability?

Does the tool implementation demonstrate a new class of capabilities?

Is the tool performance predictable?

Does the tool support a well-defined set of test cases?

Does the tool support only a narrow subset of known test cases?

Has the tool been tailored specifically to a narrow set of test cases in order to achieve a perceived level of success?

Does the tool support the research goals?

Does the tool implementation require a reevaluation of the research problem?

Figure 5. Criteria for Evaluating Phase 3: The Method Implementation.

Tool building is the essential work of the information scientist. It is an iterative process. Thus, toolmakers may not always discard the tool that doesn't work. Since the potential of new technology is always a step ahead of the toolbuilder, the tool must be constantly evaluated to see if it can be made to work. Can existing tools be improved and applied to a broader class of problems? The research community should know the success or failure of this effort apart form the research supported or enabled by the tool. In addition, if the implementation satisfies just a single or narrow class of problems, it may still contribute to the body of knowledge.

Phase 4. Criteria for Evaluating the Research Experiment Design

During this stage, tools facilitate the conduct of the experiment. Test cases demonstrate the range and functionality of the tool. The criteria for phase 4 are presented in Figure 6.

Are the test cases qualitatively different?

Do the test cases demonstrate the full range of research goals?

Do the test cases support the assumptions and limitations embodied in the tool?

Do the test cases support a generalization of the tool?

Do the test cases support a definable subset of the problem domain?

Do the tool's performance criteria reflect standards accepted by the field?

Figure 6. Criteria for Evaluating Phase 4: The Experiment Design

Cohen and Howe (1988) discuss six familiar scenarios for the experiment's design:

- *Comparison Studies.* The researcher employs "before/after analysis" or "control/experimental groups" to determine if the tool enhances some variable of the experiment such as speed, user interface, or performance.
- *Direct assessment.* Human judgment provides qualified subjective scoring where there may be too many test cases or outputs for the researcher to evaluate in any organized or automated manner. Case studies often require this scenario.
- *Ablation and Substitution Studies.* The performance of individual components in a tool may be evaluated by removing or replacing components. The tool builder is generally concerned with replacing existing components with better ones.
- *Tuning Studies*. The tool is tuned to a particular test case to see how much performance can be improved. While this approach is justified for the problem at hand, it is pursued at the expense of generalizing the results.
- *Limitation Studies*. Most tools work best in a limited domain. How robust is the tool when tested at its limitations? Does it fail gracefully? This method is important where tool performance is critical over a required operating range.

- *Inductive Studies*. The generality of the tool can be substantiated by solving new and different test cases. Even though a claim of generality may not be made, tools are often applied to new problems and adapted as required.

An important goal of this stage is to convince the research community that the invention, development, study and use of the tool is a scientifically rigorous evolution, independent of the research results. In many of these scenarios, the development of survey tools is critical to success. A goal of information science is to develop standard tools for measuring phenomena in organizational environments.

Phase 5. Criteria for Evaluating Research Results

The research must be evaluated not only in terms of the research it enables, but also in terms of tool performance. The criteria for this phase, presented in Figure 7, are to: 1) measure the performance of tool when applied to the tasks of the research, 2) determine the usefulness of the tool in terms of user satisfaction, 3) ascertain validity of assumptions and limitations, 4) determine contribution of the tool to the body of knowledge, 5) determine general areas of application, and 6) consider future tool development. If possible, the tool should be evaluated using accepted standards. If standards do not exist, then the tool must be evaluated under strict controls acceptable to the research community and an effort made to establish a standard.

Did the tool perform as predicted?

Are the initial assumptions still valid?

Are the limitations still valid?

Have the performance goals been met?

What was learned by the research?

What did users tell you about the research results?

Is there a clear relationship between the tool and the results?

Can this relationship be generalized to a class of problems?

Do the results make a contribution to the body of knowledge?

Do the results suggest future research directions?

Can the tool be adapted to other areas of scientific study?

Figure 7. Criteria for Evaluating Phase 5: The Research Results

6. INFORMATION SYSTEMS GRADUATE RESEARCH

Graduate research is knowledge work which must be properly managed to produce good results. The research topic may address a problem, hypothesis or question which is supported by a feasible methodology. Among other characteristics, good topics fill a need, have a base of theory, are amenable to research methods, and have more than one potential outcome. Research should contribute knowledge or generalizations through new or improved evidence, methodologies, analysis, concepts, and theories [Davis and Parker, 1997].

IS applied research, especially that supporting research in other disciplines, is often not recognized as valid scientific work, but merely as software development. Yet society and the community of scientists continue to look to information science for the tools to enable research and solve problems within complex business models. This issue is extremely important because IS faculty engaged in applied research are doubly challenged: even those with many years of industry experience find it difficult to teach a general IS curriculum and keep up-to-date with rapidly changing technology and organizational needs. Applied research enhances the skills of IS faculty; unless this work is supported and funded, both faculty and, perhaps more important, potential graduate students will be lost to industry.

To address these issues, tool building and utilization within the research context should be an important component of the information science curriculum. When informational tool building and utilization supports and enables research, there must be an equal place at the table for information scientists. Their work must be recognized, validated, promulgated, and funded in academia and industry. Information science researchers do not seek to reduce the requirements for good science, but rather to establish reasonable bounds on applied research in information science within a model supporting the intuitive, exploratory and heuristic efforts involved in tool building and utilization.

7. RECOMMENDATIONS

1. The criteria presented in this paper should be studied, used, and refined in graduate research programs with the goals to achieve a universal applied research model in informational tool building and utilization, a generalization of results, and meaningful contributions to the body of knowledge. As Cohen and Howe point out, this approach will lead to non-traditional publications addressing topics like short studies of existing systems, reports of negative results, and periodic progress reports over the life of long-term projects.

2. Information science faculty should encourage and support project oriented graduate research in tool

building and utilization within these criteria. The goal is to increase interdisciplinary projects and projects with industry focusing on applied research in tool building and tool utilization. Academicians, practitioners and students should be indoctrinated in the importance of informational tool building and utilization. Researchers in all disciplines should be made aware of the scientific value provided by tools that support, enable, and extend their research. By applying the criteria presented in this paper, software development projects may be extended or refined to provide applied research opportunities.

3. Funding should be sought specifically for applied research in tool building and utilization. The objectives of IS tools supporting other research projects should be separately stated and funded in proposals. Grant reviewers must be educated in evaluating applied research in IS tools.

4. If these goals are to be achieved, new paradigms for applied research in informational tool building and utilization are appropriate and must be established, promulgated, and refined by academicians, researchers and practitioners.

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