METHODOLOGICAL KNOWLEDGE

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Summary

Skill in the use of the tools of research is obtained in academic settings where the objective of the process is two-fold: the creation of new knowledge and the training of personnel in research techniques. The tools of research are applied to obtain the solutions of practical problems, most often in non-academic settings.

1. Introduction

The basic focus of this article is the elucidation of how the tools of scientific investigations are deployed and interpreted. Research is the process of inquiry. The central implication of the research process is a quest for knowledge, data, or truth. “Inquiring” implies “questioning” and success in research often hinges on asking the right question. Progress in science and technology depends upon the application of the tools of research. By common agreement, the output of the processes of scientific research is knowledge and knowledge need not have immediate practical uses. Indeed, some commentators go so far as to distinguish “knowledge” from “practical knowledge” when describing the knowledge that is gained in academic settings as opposed to knowledge obtained in other settings such as industrial laboratories. This distinction is really based on a narrow definition of “usefulness” which is often a temporal question. Knowledge gained in academe can be found useful generations after its discovery or, indeed, can be immediately useful, that is to say “practical,” which is often the commercial imperative. Progress in technology is also dependent on research—applied research, the output of which is a useful application such as a better laser or a grain hybrid that is resistant to drought. Thus, both scientific research and applications research involve an understanding of the research process, but the application of that process is focused on distinctly different desired outcomes.

Historically, most students have learned about research methods in the context of “scientific research” experiences, even though the output of that experience is knowledge and not necessarily useful applications. The interesting dichotomy is that most (~90%) graduate students who acquire acceptable research skills do so in the context of science, but they often express these skills in an applications environment.

The genesis of current ideas regarding research can be found in early nineteenth century Germany, for it was there that ideology and interest came together to turn research into the university phenomenon we know today. It was there that the principle of “a unity of research and teaching” was first established by Wilhelm von Humboldt, who offered the seminal formulation for the modern research university:

One unique feature of higher intellectual institutions is that they conceive of science and scholarship as dealing with ultimately inexhaustible tasks: this means that they are engaged in an unceasing process of inquiry. The lower levels of education present closed and settled books of knowledge. The relation between teacher and pupil at the higher level is a different one from what it is at the lower levels. At the higher level, the teacher does not exist for the sake of the student. Both teacher and student have their justification in the common pursuit of knowledge. (Quoted by B.R. Clark, Places of Inquiry, Berkeley, University of California Press, 1995, p. 253.)

From the early nineteenth century, institutions of higher education changed forever. Where once they were primarily the presenters and defenders of dogma, they became the discoverers of new knowledge and the crucibles where old and new concepts became focused on producing a new view of “current knowledge,” which itself was malleable under the scrutiny of some knowledge that will be revealed in the future—the process Humboldt described as the “unceasing process of inquiry.”

Humboldt’s basic vision has become expressed differently in different parts of the world, but the basic idea—a unity of research and teaching—can be found intact in the educational systems of the countries where research has flourished—Germany, Great Britain, the United States, France, and Japan. The Humboldt idea of a unity of research and teaching is, perhaps, inadequate in an era of mass education. The transformation of academic institutions into loci of mass higher education has created a tension between the traditional (in the Humboldt sense) tasks of academic inquiry and the education of students beyond the secondary level. The challenges and requirements of societal needs for advanced labor training on a massive scale, which are often met more rapidly by applications research, may ultimately prove incompatible with the Humboldtian ideals. A sharp increase in the perceived applications research needs at the expense of academic research could, conceivably, undercut the creation of new knowledge, which is a critical component of applications research.

In some countries, national interest (perhaps only temporarily) has dictated an emphasis on certain disciplines (e.g., engineering in Japan and the biological sciences in the United States). But in all these countries, the unity of teaching and inquiry exists. That process of inquiry incorporates the fundamental tools—the methodologies—of scientific research.

2. Scientific Research

The collective judgment of scientists, in so far as there is substantial agreement, contributes to the body of scientific knowledge. Most of that body of science is established in a more-or-less systematic process involving the collection and organization of data (observations) and the formulation of hypotheses that then dictate the collection and organization of other kinds of data. The focus of this process—often called the scientific method—is to provide answers to questions addressing the description of nature in an attempt to understand the natural world. The ultimate success in science is dependent upon the skills of scientists to ask the "right" question in the context of the perceived problem associated with understanding nature. Why should a scientist choose one problem over another, to ask one question rather than another? The over-riding personal interest of each scientist is one of the most important criteria used in making the choice of problem to be investigated. Because scientific research is not a routine process but requires originality and creative thought, uninterested researchers are unlikely to produce the new ideas necessary for progress. From this point of view, the pursuit of science is a highly personal and often all-consuming undertaking and its outcome is unpredictable. The problem of interest to the scientist should address the current, larger view of nature. It is at this highly personal moment—the choice of problem—that a portion of the "usefulness" of the research outcomes is determined. The results (perhaps accidentally) could have immediate application or less obviously applicable new knowledge could result. In either case, the important outcome is another trained researcher; the knowledge gained, whatever its character, is secondary. The pursuit of science is often not focused (directly) on answering practical questions, although the processes of science can often be used successfully to answer practical questions.

3. Applied Research

The scientific research paradigm applied to practical problems is often described as applied research. The distinction that is often made between scientific research and applied research is not meant to suggest that one is better or worse. It is merely a convenience that focuses on outcomes. In the vernacular, the outcomes of scientific research are not thought of as practical and, perhaps, not deemed by society to be as useful as those of applied research. However, history has shown that, without the science as background, applied research founders on the reefs of ignorance. The usefulness of science to society is dependent on the existence of an infrastructure of knowledge derived from pure science, no one piece of which is a priori discernibly more important than another. In other words, it is often not possible to decide which piece of scientific research will be necessary to support a given piece of applied research, but it is possible to conclude that all new knowledge gained through research is ultimately important.

Applied research problems are often assigned to research workers by higher authorities who have societal goals, in contrast to scientific research that is driven by individual curiosity, unfettered by practicality. It is important for investigators who are to carry out applied research to know as much as possible about the background of the applied problem—how it arose, why it is important, and what will be done with the results. The research director in an applied research environment, who starts with personnel who are adequately trained in research, must be very careful to delineate such issues because most new applied research personnel have acquired their training in the context of a scientific research environment—academe. In other words, research training is often experienced in an academic environment (where the science is preeminent), but personnel so trained often express their skills in an applied environment.

Research directors in applied research environments must be highly skilled with respect to the way they deal with research personnel. New personnel who have been trained in academic—scientifically based—environments must be nurtured to apply their research skills to practical problems. The research techniques may be the same, but the outcomes are clearly different. Thus, applied research directors must get personnel to focus on practical goals, those associated with applications, as opposed to the answers to questions formulated from the point of view of personal curiosity. Several psychological obstacles loom before research directors in applied research environments. Having probably been trained in academe (on a scientific problem), they must overcome a natural instinct to work in scientifically interesting areas. In many cases, this is a very difficult "habit" to overcome. Additionally, issues of secrecy, which are generally absent in scientific research, may become important in applied research. Losses in research efficiency invariably occur when secrecy, either industrial or military, becomes important. Science does not flourish when secrecy is an important component of research, but secrecy might be a critical issue in applied research. Issues of secrecy in applied research laboratories often lead to redundant activities that, from one point of view, breed inefficiency in parallel applied research groups.

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Biographical Sketch

Joseph J. Lagowski is professor of chemistry (since 1967, in the Department of Chemistry and Biochemistry) and professor of education (since 1973, in the College of Education) at The University of Texas, in Austin, Texas. He received his Ph.D. in inorganic chemistry (non-aqueous solutions) from Michigan State University. An appointment as a Marshall Scholar at Cambridge University led to a second Ph.D. (organometallic chemistry) from that institution.

Professor Lagowski''s scholarly interests include both "bench chemistry" and various aspects of chemical education. His work in the former area has focused on the influence of the solvent on the chemistry of unusual species—from the point of view of aqueous chemistry. His work in organometallic chemistry includes various aspects of -complexes. His other major scholarly work has been in chemical education. In the early 1960s, he became interested in the use of interactive computing to assist the educational process. He and his students have identified those areas of teaching for which computer methods are maximally effective.

Professor Lagowski''s research and education interests have also manifested themselves in his service to the professional community. He served as editor of the Journal of Chemical Education (1979–1996), where he was instrumental in bringing into reality the advantages of technology in teaching chemistry.
Professor Lagowski received the CMA Award for Excellence in Chemistry Teaching (1981); he was elected a fellow of the AAAS (1982); he was named a Piper Professor for Outstanding Scholarly and Academic Achievement (1983); he received the ACS Award in Chemical Education (1989); he received the Southwest Regional ACS Award (1996); and the James Flack Norris Award (1999).