Taking the Vital Signs of a Building: Understanding Building Performance by Taking a Building's Vital Signs

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ABSTRACT

The impact of building design decisions on energy consumption, occupant health and comfort, and environmental quality is an area where design professionals need complete understanding. Unfortunately, building technology courses at most schools of architecture are typically organized as a series of lectures and examinations, rarely providing an opportunity for integrating design with technology issues. "Hands-on" experiences with real building technologies and performance are rarely provided in the mainstream curriculum. This paper discusses methods for on-site investigation and measurement of building performance through economical, simple, and innovative means available to professionals and students in the design professions and building industry. A brief of the Vital Signs Curriculum Project, an endeavor that challenges designers to adopt a "detective's eye" in examining design intent and building performance through investigations of occupied buildings, is included along with a basic model for field measurement and experiences from recent training sessions.

SYNOPSIS OF THE VITAL SIGNS PROJECT

The Vital Signs Curriculum Project was developed to introduce investigations of built projects—through observation, measurement, and analysis—into the curricula of schools of architecture (Kwok and Grondzik 2000; Kwok et al. 1997, 1998). With a focus on energy efficiency, occupant comfort, and building system performance, the Vital Signs Project provides a broad point of entry to the multiple experiential layers that make buildings intriguing (and design so complex). The best source of detailed information on the Vital Signs Project is the Vital Signs World Wide Web site, which provides project objectives, history, resources, and results.

The kernel idea for the Vital Signs Project began during a series of discussions at Society of Building Science Educators (SBSE) retreats, where faculty discussed innovations to existing architecture curricula and identified the need for a revised pedagogic approach. We recognized that the discipline of architecture lacks a tradition of evaluating its own products (buildings) and thus misses an important educational opportunity for students and practitioners. Architects have enormous power to affect economic, environmental, and social development through their work, but they lack the tools to assess how well they've met the needs of the owners and occupants of their projects. This unique group of faculty attending the annual retreats developed a case study model, describing the parts that would make an ideal case study, both to teach and learn from. Beginning with a *hypothesis*, a key challenge in conducting a case study is the development of a focused statement for field investigations—a testable statement, that defines the scope of the investigation. Having stated a hypothesis, the next part should describe *methods* used to gather and analyze data addressing descriptive information, occupant response, and physical performance. The *results* section should present the findings of the field work in a clear succinct fashion. A *conclusion* regarding the investigation's hypotheses, *appendices*, and future *design directions* are also included.

A diverse range of materials and activities were developed to launch the Vital Signs Project and encourage faculty and student adoption of the Vital Signs approach. (1) Resource

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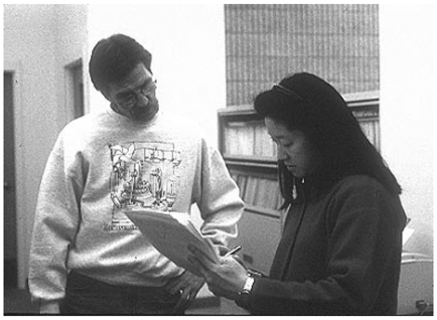


Conducting surveys in an office (Eugene, Oregon).

Attaching data loggers in a crawl space (Portland, Oregon).

Installing data loggers to measure stack effect (Tampa, Florida).

Figure 1 *Examples of Vital Signs site visit activities.*

packages addressing building performance topics that provide principles, concepts, annotated bibliography, and protocols for carrying out building investigations; (2) summer training sessions for faculty to ease their learning curve; (3) case study incentive grants to support a first wave of published results; (4) case study competitions to encourage student participation; and (5) a traveling equipment toolkit to provide instrumentation resources.

Student examinations of buildings have proved to be exceptionally valuable as a means of fostering learning about a wide range of architectural issues. This finding has significant implications for the way we teach and how students learn, how we prepare students for the design professions, and on the quality of buildings that students will design and see constructed in the future. Outcomes of this approach to architectural education and descriptions of faculty and student experiences during recent Vital Signs workshops are the focus of this paper.

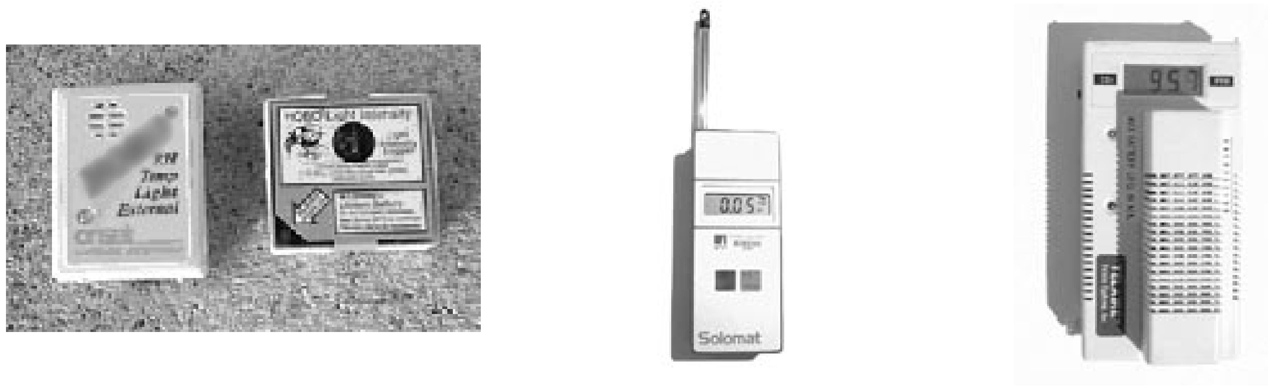
MODEL OF BUILDING EVALUATION

The impacts on architectural education (and thus building design) likely to result from implementing the Vital Signs approach can be deduced from the project's suggested investigative process (Grondzik 1998). Although not a formal or mandatory procedure, most successful case study investigations involving on-site measurements will generally include the following elements:

- **Identification of the building and objectives**. A preliminary building visit that is intended to result in the formulation of reflective questions about the building. A review and discussion of such questions so that the most fruitful questions may be developed into hypotheses regarding the building and its performance.
- **Hypothesis development.** Establishment of clear and testable hypotheses that are reasonably "narrow"—in other words, dealing with shading on the south façade is preferable to dealing with shading on the whole building (in terms of a hypothesis).
- **Establishment of methods.** The development of appropriate investigative methodologies and assembling available equipment to address these hypotheses.
- **Field investigation.** One or more preplanned site visits to implement the investigative methodologies (as illustrated in Figure 1). Use of low- to-moderate cost measurement equipment when available and appropriate to the investigative objectives.
- **Analysis of the data.** Making sense of the information resulting from these on-site visits, measurements, and observations.
- **Framing conclusions and design lessons.** Answering the original questions and posing questions for future study. Preparation of a case study to present the process and results of the investigation to interested parties (typically via the World Wide Web). Outlining the design lesson learned.

Studies of building environments vary widely in depth and scope depending on the experience of those involved and the time allotted for the development of ideas. Case study investigations by students at universities have ranged from one-week building investigations to semester-long studies. Much can depend on the accuracy of the measurement technology and how the data are collected. Surprisingly (or perhaps not), student case studies have repeatedly developed information of substantial practical interest to the building owner/manager.

Architecture faculty at progressive schools have implemented the Vital Signs case study approach by modifying their curricula and including investigative experiences as an integral part of large lecture courses, seminars, studios, and independent study courses. Special elective seminars have been adopted at several universities, allowing students time to develop in-depth studies of nearby buildings. To date 18 schools of architecture have provided approximately 50 case studies through the Vital Signs website, one university has established a Case Study Hall of Fame, and numerous other case studies are posted to various university websites. These



Data loggers Anemometer Carbon dioxide monitor

Figure 2 *Portable instrumentation typical of the Vital Signs tool kits.*

case studies are available to any interested party, including designers and building owners.

From 1995 to 1998, Vital Signs summer training sessions were held in San Francisco, orienting architecture faculty to the resource packages, measurement devices, and the case study process. Based upon these experiences and with funding from the U.S. Department of Education, the authors and other Society of Building Science Educators faculty have recently tested the viability of regional "Agents of Change" training sessions of varying lengths. Oregon graduate teaching assistants, with "expert" faculty advisors, act as trainers for attending faculty and teaching assistants, leading participants through tool training exercises and a mini-case study process with the intention of inspiring participants through experiential learning.

MEASUREMENT DEVICES

"Tool kits" were developed by the Vital Signs investigators to provide assistance to faculty who wish to utilize instrumentation during on-site investigations. Vital Signs tool kits provide a set of relatively low-cost measurement and analysis equipment (including those items shown in Figure 2) that might be readily employed by architecture students – or architects, engineers, contractors – in pursuit of building performance data. Full information on each item of equipment (model number, cost, manufacturer, and purpose/usage) is available on the Vital Signs website. The tool kit and supporting information represent a substantial resource for faculty not fully familiar with building science instrumentation. Equipment appropriate to a particular investigation (such as determining the thermal properties of glazing) may be selected from the numerous equipment items that comprise the tool kits. The Vital Signs Project purchased several complete tool kits (with shipping containers) and has made them available to interested faculty via semester- or year-long loan programs. The tool kit loan program has been very popular with Canadian and U.S. schools that do not have the resources to purchase full or partial kits of their own.

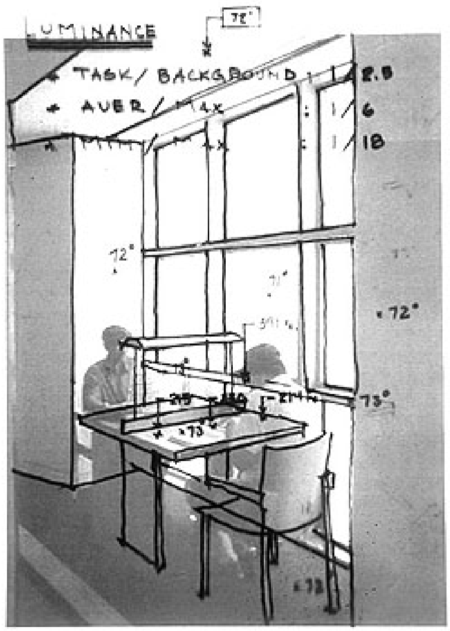
Many measurement devices may also be available from local sources. Gas and electric utilities, for example, will often lend equipment to building owners and designers who have projects within the company's service territory. A California utility company, for example, operates a tool lending library for its customers at its energy center in San Francisco. Since the technology of measurement has changed so rapidly and micro data-processors have become more economical than their larger, more expensive precursors, many academic institutions have acquired equipment collections in departments of architecture, engineering, physics, public health, geography, and chemistry.

FIELD INVESTIGATIONS

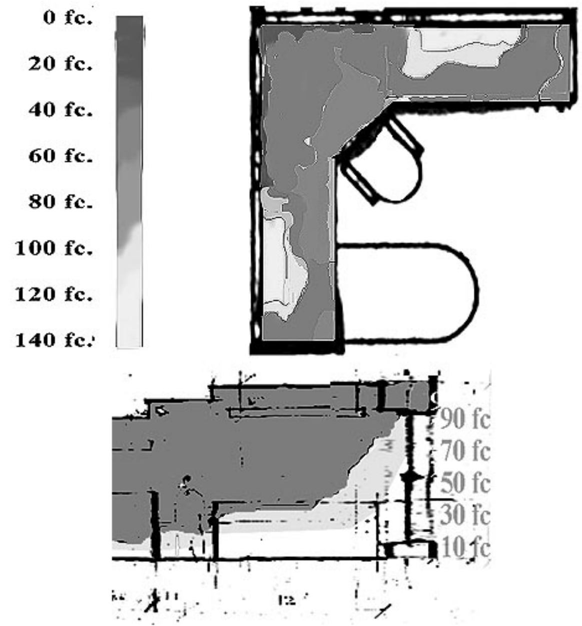
The core activity of the Vital Signs case study is the actual building investigation itself—the part that students seem to enjoy most. The process depends on the nature of the study, the topic, and the general category of measurements taken—"snapshot" measurements at a specific point in time or time series recordings at a specified interval. Evaluating the delivery effectiveness of a residential furnace will be substantially different from a study of occupant perception of visual comfort. The first study might involve comparisons of seasonal utility bills with temperature measurements taken directly from air intakes and diffusers, while the second could involve occupant surveys, measurements of luminance, and comparisons of physical measurements to acceptable limits set by the Illuminating Engineering Society (IES). Experience has shown that methodologies that are organized, well-conceived, and pre-tested result in the most successful case studies.

FINDINGS AND CONCLUSIONS

Graphic and numerical information collected during field investigations is frequently displayed as a series of photo images, tables, or graphs, depending on the type of information involved. Architecture students are encouraged to



Luminance and temperature measurements superimposed over photo image at the San Francisco Public Library.



Contour map and section of illuminance measurements at the National Audubon Society Headquarters in New York City.

Figure 3 *Graphic representations of luminance and illuminance.*

develop useful ways to visualize data, thus making it possible to identify connections between design and performance, between the visible and the invisible. Graphically, an image needs to communicate information clearly and simply but not in a dense manner; with aesthetic and creative appeal, but not so that it distracts the reader from critical information.

WORKSHOP EXPERIENCES

Tool Training

Vital Signs workshops typically begin with an intensive tool training session. Participants are introduced to measurement devices through a series of exercises in and about a building to find a range of values for variables such as interior illuminance, solar radiation, electric current, and surface temperature, an activity proven to be both exciting and effective. Following the tool training, participants receive an introduction to a pre-selected building presented by the architect, facility manager, or someone with knowledge of the design process and the functioning of the building.

Conducting a Case Study

Participants are introduced to the case-study process by actually conducting a mini-investigation of a pre-selected candidate building. Although some semblance of the full case study development process is provided during training sessions, a full exploration of the case study process typically requires a semester-long period (in an academic setting). Students typically require time to ingest, digest, and ponder new ideas and ways of thinking. On the other hand, interesting and useful results have been consistently developed during workshops when less than a day has been devoted to on-site measurement and subsequent analysis.

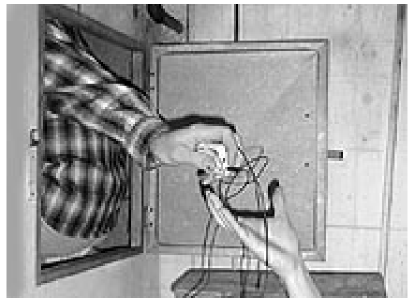
Observed Outcomes

Observations from several actual field investigations during recent training sessions have provided anecdotal data on *experiential learning* and *peer-to-peer education*, both powerful vehicles to expose students to the scientific method, instrumentation, development of communication skills, and the like.

Experiential Learning. Students are actively involved in learning as they develop building case studies (Figure 4). They form inquiry questions and hypotheses, collect data by observation and measurement with handheld sensors or left-in-place data acquisition equipment, and eventually analyze the successes and failures of building design. We have found that students who use the building performance case study approach consistently learn the underlying technical material at a deeper and more intuitive level and are better prepared to incorporate the lessons into their design process. This experiential/experimental approach moves the student from being a passive recipient of information presented in the classroom to being a more active participant in the journey of discovery. The same can likely be said for architects, engineers, and contractors who learn about building performance using the Vital Signs approach.

Peer-to-Peer Education. Student-to-student interactions become common and an environment where peer-to-peer

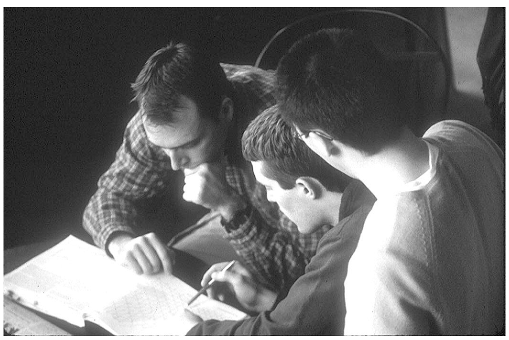
Measuring solar radiation (Berkeley, CA).



Data logger hand-off from inside ductwork (Portland, Oregon).

Taking surface temperature readings (Milwaukee, Wisconsin).

Figure 4 *Examples of experimental, activity-based learning.*



Peer-to-peer discussion about the psychrometric chart at a recent training session.

Peer-to-peer instruction; University of Oregon elective course.

Figure 5 *Examples of peer-to-peer learning.*

learning can occur often develops (as suggested in Figure. 5). For example, during a discussion of glare one student may suggest that glare is a physical phenomenon—only to be corrected (constructively) by a peer who notes that glare is a perception. This sort of interaction most typically occurs during the development of investigative methodologies. When peer-to-peer give-and-take falls short, faculty advisors can step in and be educationally effective because of a need to know (now!) on the part of the student.

Peer-to-peer learning often translates into peer-to-peer training in the absence of the instructor. During one case study, a group of students taking surface temperature measurements using a remote infrared temperature sensor was "trained" on the spot by another team conducting similar measurements with different equipment. The synergy of students recognizing the need to accomplish a task and the willingness of others to help out by sharing what needs to be done is a powerful educational strategy, and one that cannot be centrally planned into a course.

Unlike students in engineering schools, architecture students receive little exposure to research skills or practice in rational thinking. Virtually no building performance information is regularly shared within the profession of architecture. Benefits and experiences from the Vital Signs training session efforts and hence the implementation of the case study approach within the curriculum will include growth in the knowledge base, meaningful opportunities to explore the successes and failures of building design solutions, and ultimately enable students, as future architects, to better align design intent with resulting building performance.

CONCLUDING REMARKS

The Vital Signs case study approach has proved repeatedly to be a powerful and exciting vehicle by which to understand architecture. This has been demonstrated in a wide range of settings. The approach can be adapted to address an exceptionally broad variety of topics and/or depth of analysis. The approach raises interesting questions about teaching philosophy and approach as a means to reinvigorate conventional (and arguably ineffective) architectural education curricula. Given time, we expect we will experience an improved design process and product as buildings become better understood through on-site analyses.

From a student perspective, we've seen exponential learning, an energetic application of textbook concepts and principles to real experiences in buildings, and what seems like longer retention of those issues because of the depth and personal nature of the Vital Signs experience. Although many of the issues addressed during an investigation may be new to students (or, at best, vaguely remembered from a lecture) it is important from a faculty perspective to not expect too little from these willing detectives. Likewise it is wise to not demand too much during a short period of time, thereby diluting the depth of experience.

The authors have thoroughly enjoyed each of the Vital Signs experiences (Kwok 1999; Oregon Case Study Hall of Fame website) with which they have been involved. All have revealed new thoughts about buildings, exposed new methods of investigation, raised questions about well-rooted beliefs, and demonstrated rapid growth in student capabilities. Probably the most difficult aspect of instructing or facilitating a Vital Signs case study is learning how to let go and back off—to let the students do as much as possible and be willing to say "this is not a sponsored research project, this is learning in progress." Faculty and student experiences have been documented in recent papers (Grondzik 1998) and informally through training session highlights during the Agents of Change training sessions in 2000-2001 (website highlights).

The benefits of the Vital Signs approach to understanding building performance would seem to be as valid, useful, and needed in the world of practice as in the world of academia. The use of actual buildings as a vehicle for Vital Signs case studies ensures the relevancy of investigative findings to the real world. Currently such investigations are occurring by happenstance. If there were more interest in post-construction performance verification, there might be more demand for such investigations by the design professions. Or perhaps the demand would come from the design professions' clients?

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For Further Reference

Agents of Change Project: A project coordinated by the University of Oregon Department of Architecture and funded by a grant from the U.S. Department of Education Fund for the Improvement of Post Secondary Education (FIPSE) to better prepare students as future teachers, architects, and stewards of the built environment by curricular innovation using the Vital Signs case study approach. http://aaa.uoregon.edu/~aoc/index.html.

Society of Building Science Educators (SBSE), an association of university educators and practitioners in architecture and related disciplines who support excellence in the teaching of environmental science and building technologies. http://www.polaris.net/~sbse/web/

The Vital Signs World Wide Web site: http://www-archfp.ced.berkeley.edu/vitalsigns/index.html.

University of Oregon Case Study Hall of Fame site: http://aaa.uoregon.edu/~ecsarchive/.