Active Assessment: Assessing Scientific Inquiry

Mentoring in Academia and Industry

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Biology is evolving rapidly, with more and more discoveries arising from interaction with other disciplines such as chemistry, mathematics, and computer science. Undergraduate and Graduate biology education is having a hard time keeping up. To address this challenge, this bold and innovative series will assist science education programs at research universities, four-year colleges and community colleges across the country and by enriching science teaching and mentoring of both students and faculty in academia and for industry representatives. The series aims to promote the progress of scientific research and education by providing guidelines for improving academic and career building skills for a broad audience of students, teachers, mentors, researchers, industry, and more.

Volume 1 Education Outreach and Public Engagement
by Erin L. Dolan

Volume 2 Active Assessment: Assessing Scientific Inquiry
by David I. Hanauer, Graham F. Hatfull, Deborah Jacobs-Sera

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Springer

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We dedicate this book to the community of scientist-educators and to all – from both sides of the divide – who aspire to join them

Acknowledgments

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1.1 Scientists as Educators

Doing science is an exciting, fulfilling activity that contributes to the collected cultural knowledge of humanity. By doing science new knowledge is created and our understanding of the world around us is increased. Unfortunately, this sense of mission and personal feelings of excitement and fulfillment so characteristic of the active scientist are lost in most science education settings. This book, as with other publications from the authors of this book, evolved from the simple premise that active scientists should be involved in and develop serious educational programs designed around real scientific research questions. Science education is too serious a purpose that scientists can leave this to others to fulfill. The authors of this book hold a deep belief that the way to advance science education is through the development of in-laboratory science education programs that bring students into close contact with the experience and realities of authentic scientific inquiry. This book is designed to help active scientists to create authentic assessments that contribute to the educational process and provide meaningful data that can be used by the scientist-educator and student-scientist to enhance the educational process within the laboratory and thus enhance science. This book was written with the understanding that scientists may not feel comfortable with educational concepts and terminology and that this is one of the barriers to the creation of more laboratory-based, authentic science education programs. It is our hope that this book will provide a clear introduction to the approach to the assessment of scientific inquiry that we have developed and used in our own laboratory educational program and that this knowledge will ultimately lead to the creation and understanding of assessment in new laboratory-based scientific inquiry educational programs.

1.2 The Context and Aims of This Book

This book deals with a very specific educational context – the in-laboratory, scientific inquiry, educational program. The issue that this book addresses is the way

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to assess knowledge development and outcomes within this setting. This book has three main aims:

1. To provide scientist-educators working with in-laboratory scientific inquiry educational programs an approach to the development of a meaningful assessment program
2. To provide scientist-educators with a comprehensive understanding of issues of educational assessment and an overview of the work that has been done by science educators concerning the assessment of scientific inquiry
3. To provide scientist-educators with a case study and specific examples of one program that utilized the approach developed in this book to the assessment of scientific inquiry.

1.3 Relevant Historical Developments in Science Education

This book finds its source in three interrelated developments in science education. The first deals with the importance of enhancing students' understanding of the procedural knowledge of scientific activity. The most widely recognized statement of this type was the National Research Council's publication of their *National Science Education Standards* promoting scientific inquiry as a core element of scientific education (NRC, 1996). Over the years since this early publication, the same message of the centrality of scientific inquiry as an educational tool has been repeated in a variety of publications and national reports. Most importantly for undergraduate science education, in another NRC report prepared by the Committee for Undergraduate Biology Education to Prepare Research Scientists for the 21st Century and entitled *BIO2010: Transforming Undergraduate Education for Future Research Biologists*, an emphasis is placed on providing students with the experience, understanding, and skills required to conduct interdisciplinary scientific inquiries within the coming century.

The second educational development consists of the movement of science education out of the classroom and into the laboratory. This direction can be seen as the most direct implementation of the concept that science education should focus on scientific inquiry. As stated by Handelsman et al. (2004), "Scientists of all disciplines have developed inquiry-based labs that require students to develop hypotheses, design and conduct experiments, collect and interpret data, and write about results" (p. 521). Extending this argument Hatfull et al. (2006) and Hanauer et al. (2006) promote (and exemplify) the transformation of the professional research laboratory into an educational arena that brings students from a diversity of disciplines, ages, and interests into a laboratory in order to conduct authentic scientific inquiries. This requires the definition of in-lab research projects that are appropriate for a variety of incoming students with different knowledge bases but still culminate in authentic scientific discoveries (Hatfull et al., 2006; Hanauer et al., 2006).

The third educational development deals with the role of the science instructor. Under the heading of "scientific teaching," Handelsman and her colleagues in a number of initiatives and publications have promoted the concept that science teaching should be directed by the same principles that inform scientific research activity. Specifically as developed by Handelsman et al. (2007) scientific teaching should involve the same levels of "critical thinking, rigor, creativity and the spirit of experimentation" as those used by scientists in their research. The concept of scientific teaching integrates the activity of conducting scientific research with the activity of scientific teaching. Importantly, the concept of scientific teaching rests upon two core principles: the need for engaging educational experiences based on an understanding of scientific inquiry and the need for evidence that will allow the evaluation of all educational activities.

The outcome of these three developments in science education is the proposition that science education should focus on scientific inquiry, should optimally take place within a laboratory setting, and be directed by the principles of scientific teaching. An educational program of this sort should engage students in the process of scientific inquiry and allow scientist-instructors the ability to measure and evaluate the quality and content of the education their students are receiving. It is this last point that the current book addresses. The aim of this book is to provide scientist-educators with a set of conceptual tools that will allow them to create an assessment strategy and assessment tools that are appropriate for the assessment of an educational, scientific inquiry program situated within a laboratory setting. This book builds upon the basic ideas of scientific teaching by providing an approach to the development of assessment tools that can be used in a variety of settings and thus allow scientists to consider carefully the quality and learning outcomes of their teaching. It should be noted that the current book addresses assessment within the confines of the educational developments specified above, namely teaching scientific inquiry through in-laboratory experiences. This is a relatively complex educational context and accordingly specific approaches to this distinctive educational setting are developed in this book.

1.4 Active Assessment Defined

Active assessment is the process through which scientist-educators develop an assessment strategy and assessment tools that provide significant information that enhances the active learning experience of students involved in the scientific inquiry process. Active assessment is a process in that the scientist-educator is actively involved in the development of their own assessment tools. In other words, the scientist-educator is an active part of the process of understanding how her/his educational programs are assessed and is in no way a passive recipient of standardized, externally created assessment tools. In addition, active assessment is based on the idea that the students who are engaged in scientific inquiry within a laboratory setting experience the assessment process as integral to their scientific inquiry process

and as a source of input that informs their work and understanding as scientists. The active assessment process requires the scientist-educator to be deeply involved in the design of an educational experience that provides serious feedback and makes the scientific inquiry process conceptually meaningful and scientifically valuable for both the instructor and student-researcher. The characteristics of active assessment can be summarized as follows:

1. Active assessment elicits significant information that can be used to assess the quality and content of the educational inquiry program.
2. Active assessment is embedded within the scientific inquiry process and reflects meaningful practice within the laboratory setting.
3. Active assessment is developed by the scientist-educator and reflects the core procedural and substantive understandings of the specific scientific inquiry process that is utilized within the laboratory setting.
4. Active assessment is meaningful to the student-researcher and provides significant feedback that contributes to the educational and scientific development of the student-researcher.

1.5 The Underpinning Principles of Active Assessment

The idea of active assessment as defined above is based on several basic principles of educational practice. The first characteristic – *Active assessment elicits significant information that can be used to assess the quality and content of the educational inquiry program* – is tied to the core concept of all assessment research that educational processes and outcomes can and should be measured. From the perspective of scientific teaching, decisions in relation to educational practice should be based on the presence of relevant and comprehensive data concerning the process and outcomes of learning. Active assessment as an approach to assessment is designed to provide quality-contextualized information that in a very direct way measures those aspects of the scientific inquiry program that represent moments of meaningful knowledge development in the student-researchers' projects. Evidence collected from the process of active assessment concerning students' knowledge can be used to evaluate the state of learning within the program by pinpointing areas in which development has (or has not) occurred. This information can be used to modify or enhance various components of the educational program. In other words, active assessment should provide the evidence through which the educational value of the scientific inquiry program can be measured.

The second characteristic – *Active assessment is embedded within the scientific inquiry process and reflects meaningful practice within the laboratory setting* – addresses the core understanding that scientific inquiry is a particularized activity and that learning science is best advanced through contextualized understanding. The basic educational principle exemplified within the in-laboratory scientific inquiry process is termed situated learning (Lave & Wenger, 1991). Situated