Veronica Boix Mansilla
Elizabeth Dawes Duraising

Targeted Assessment of Students' Interdisciplinary Work: An Empirically Grounded Framework Proposed

The demand is clear. To thrive in contemporary knowledge societies, young people need not only to develop insights and modes of thinking that are informed by a variety of disciplines but also to integrate these forms of knowledge effectively—be it to develop a personal position about stem cell research, prepare for a career in intellectual property law, or understand global efforts to eradicate poverty. Interdisciplinarity is increasingly the hallmark of contemporary knowledge production and professional life. Preparing young people to engage in the major issues of our times requires that we nurture their ability to produce quality interdisciplinary work (Boix Mansilla et al., 2000; Boix Mansilla, 2005, 2006).

Colleges and universities increasingly offer "interdisciplinary" programs as markers of their capacity to prepare a new generation of thinkers and professionals (Lattuca, Voigt, & Fath, 2004).[1] Yet the rapid

We thank the Atlantic Philanthropies for their generous support of our work. We are grateful to the faculty, students, and administrators at the Center for Bioethics (University of Pennsylvania), and the programs of Human Biology (Stanford University), Interpretation Theory (Swarthmore College), and NEXA (San Francisco State University) who participated in our study. We thank our research colleagues Howard Gardner and Matt Miller for their feedback on prior versions of this piece and Svetlana Nikitina for contributing to data collection.

Correspondence concerning this article should be addressed to Veronica Boix Mansilla, Interdisciplinary Studies Project, Project Zero, Harvard Graduate School of Education, 124 Mt Auburn Street, 5th Floor, Cambridge, Massachusetts 02138. E-mail: veronica@pz.harvard.edu

Veronica Boix Mansilla is Principal Investigator of the Interdisciplinary Studies Project, Project Zero, Harvard Graduate School of Education. Elizabeth Dawes Duraising is a researcher in the same project and a doctoral student at the Harvard Graduate School of Education.

The Journal of Higher Education, Vol. 78, No. 2 (March/April 2007)
Copyright © 2007 by The Ohio State University

growth of these programs is accompanied by an often-warranted concern about the quality of learning taking place: What constitutes quality work when individual disciplinary standards are inappropriate or inadequate? Greater emphasis on evaluation and accountability across the academy (Astin, 1993; Banta, 2002; National Academies, 2005) accentuates the ambiguity surrounding quality assessment of interdisciplinary work. Faculty and programs remain ill-equipped to advance students' understanding of complex issues or to evaluate the impact of interdisciplinary programs on firm grounds, making interdisciplinary courses and programs vulnerable to reduction or closure (Schilling, 2001).

In this article we present a study of experienced faculties' beliefs about the assessment of interdisciplinary student work. Our results shed light on the qualities they associated with more and less accomplished interdisciplinary student work and on the particular assessment challenges posed by work at disciplinary crossroads. Building on an educational research tradition that favors the development of "usable knowledge" (Lageman, 2002), our findings are integrated into a framework designed to focus evaluators' attention on the key qualities of interdisciplinary work worth attending to in assessment. In what follows we begin by reviewing relevant literature on assessment and interdisciplinary learning in higher education. We proceed with a description of our study and introduce our framework for targeted assessment. In conclusion, we revisit the challenges and possibilities of more rigorous assessment and pedagogical support of interdisciplinary work.

Assessing Interdisciplinary Understanding

Since 1980, attention to assessment in higher education has been fueled by the recognition that insights into student progress and outcomes can inform direct instruction as well as programmatic improvement in teaching and curriculum (Astin, 1985; Ewell, 1984). More recently, concern about accountability (Ewell, 1991) has led to a growing array of quality measurement tools. Today, the field of assessment in higher education is characterized by its multiplicity of purposes (e.g., supporting learning, gate-keeping and certification, policy review), units of analysis (e.g., individual vs. groups, process vs. outcomes), approaches (e.g., performance based tasks, standardized tests), and stakeholders (e.g., faculty, students, the state).

Within this broad and often contentious landscape, our study focused on faculty's close analysis of student work produced in interdisciplinary courses, such as integrative final papers, written examinations, and cap-

stone presentations. In other words, we focused on assessment practices geared primarily to eliciting, characterizing, and informing students' interdisciplinary understanding. Our study builds on the premise that assessment conducted with the aim of certification or program evaluation must stand on valid indicators of what counts and what does not count as accomplished student work—that is, indicators that have proven elusive in interdisciplinary education to date.

Proponents of assessment innovations in interdisciplinary teaching echo the literature on performance-based assessment that has tended to dominate progressive educational discourse since the early 1990s (Ewell, 1991; Hutchings, 1990; Shulman, 1987; Stowe & Eder, 2002; Wiggins, 1998). This literature converges on a few basic premises: (a) assessment tasks should invite students to build and demonstrate mastery of "whole" performances; (b) criteria and standards should be shared between faculty and students; and (c) assessment should be ongoing and should provide feedback to support learning. The growing impact of this literature on practice has resulted in a plethora of information-gathering tools such as rubrics, portfolios, and inquiry logs. While instructive in shedding light on *how* to gather information about qualities of student understanding, this literature is limited in its ability to indicate *what* substantively to assess in interdisciplinary courses—that is, the markers of quality interdisciplinary work.

In the literature directly addressing interdisciplinary education, knowledge about assessment must be gleaned from reports of individual faculty experiences (Field, Lee, & Field, 1994; Field & Stowe, 2002; Haynes, 2002; Jacob, 2002; Klein & Newell, 1998; Lattuca, 2001; Schilling, 2001; Seabury, 1999; Smith & McCann, 2001). Some scholars have attempted to list the skills required for interdisciplinary work and so, by implication, have outlined criteria for assessment. For example, Kavalovski (1979) described the key goals of interdisciplinary education as the integration of knowledge, freedom of inquiry, and innovation. Newell and Green (1982/1998) concurred with these goals, adding that deductive reasoning, reasoning by analogy and, in particular, synthetic thinking should also be included. More recently, Newell (1998, 2002) identified 21 cognitive skills involved in integrative work, ranging from critical thinking to sensitivity to bias and ethical issues. Similarly, in their overview of conditions for effective interdisciplinary learning, Lattuca, Voigt, and Fath referred to outcomes such as "promot[ing] the development of sophisticated views of knowledge and learning" and "build[ing] students' capacity to recognize, evaluate, and use differing (multiple) perspectives" (2004, p. 44). By emphasizing general cogni-

tive skills, this literature points to processes present in interdisciplinary (as well as disciplinary) work. However, it is limited in its ability to shed light on the substantive knowledge base of student understanding and the unique demands of disciplinary coordination.

One exception is Wolfe and Haynes' construct validation of a scoring rubric for expository, research-based interdisciplinary writing (2003a; 2003b). The rubric outlined 55 criteria, under the categories of drawing on disciplinary sources, critical argumentation, multidisciplinary perspectives, and interdisciplinary integration. In its initial incarnation, the rubric elicited high inter-rater reliability, but it presented two limitations: (a) disciplinary reasoning was assessed solely by examining students' use of sources, and (b) the multiple criteria proved too unwieldy for the rubric to be viable.

The lack of clarity in the literature about how to define substantive indicators of quality interdisciplinary work is not surprising. Interdisciplinarity is an elusive concept (Klein 2000, 2002; Klein & Newell, 1998). Stated definitions are varied, and so are the enacted definitions that tacitly guide teaching practices in various institutions. The term is adopted to characterize a broad array of endeavors—from a computational biology assignment on gene regulation to a poststructuralist critique of media and democracy. It is used to describe work that integrates various disciplinary traditions, themselves embodying often conflicting assumptions about how to evaluate learning.

Building on a clear—though admittedly stringent—definition of interdisciplinary understanding, this empirical study complements the performance assessment literature's emphasis on *how* student work is assessed by gathering data on *what* expert practitioners look for in student work. It captures thinking skills associated with a range of intellectual work as well as the unique ways in which disciplinary knowledge and modes of thinking are brought together in interdisciplinary work. Recognizing the disparity of disciplinary practices and combinations represented in interdisciplinary courses, our study addresses a broad range of disciplinary combinations and student work products. We examine two empirical questions:

1. What qualities do experienced faculty in well-recognized interdisciplinary undergraduate programs ascribe to accomplished student interdisciplinary work?
2. Can the qualities identified be integrated into a coherent and usable framework designed to assess student interdisciplinary understanding?

Study Overview: Definitions and Research Design

We define *interdisciplinary understanding* as the capacity to integrate knowledge and modes of thinking in two or more disciplines or established areas of expertise to produce a cognitive advancement—such as explaining a phenomenon, solving a problem, or creating a product—in ways that would have been impossible or unlikely through single disciplinary means (Boix Mansilla et al., 2000).[2] This definition builds on a *performance* view of understanding that privileges the capacity to *use* knowledge over that of *having* or *accumulating* it (Perkins, 1998). From this perspective, individuals understand a concept when they are able to apply it—or think with it—accurately and flexibly in novel situations. Also central to the proposed definition is the upholding of disciplinary standards in interdisciplinary work. Disciplinary understanding builds on knowledge and modes of thinking that have survived the scrutiny of expert communities using commonly agreed upon methods and validation standards (Gardner & Boix Mansilla, 1994; Boix Mansilla & Gardner, 1999). In this type of work, the integration of disciplinary perspectives is a means to a purpose, not an end in itself, and multiple possible integrations are viable. The merit of an integration is to be assessed against the very purpose of each interdisciplinary enterprise. Consequently, no standard metric applies to work produced for a variety of aims. Instead, a dynamic framework is needed—one that calls attention to the purpose of a particular piece of work as a benchmark by which to judge its successes and limitations.

In the fall of 2002, participants in our study were interviewed and observed at four well-recognized interdisciplinary undergraduate programs: Bioethics at the University of Pennsylvania [BioE], Interpretation Theory at Swarthmore College [IT], Human Biology at Stanford University [Hum Bio], and the NEXA Program at San Francisco State University [NEXA] (see Appendix A). Programs were selected on three grounds: (a) they reflected longstanding commitment and accumulated experience in quality interdisciplinary education; (b) faculty were willing to reflect about the nature of interdisciplinary teaching and learning; and (c) collectively, the programs represented a broad range of disciplinary emphases and combinations. Senior administrators were asked to select faculty informants within each program who (a) had at least 5 years of experience in interdisciplinary teaching, (b) were particularly thoughtful about and committed to their teaching practice, and (c) whose courses, collectively, represented a variety of disciplinary combinations (N = 41) (see Appendix B). To provide further context for our

faculty interviews, a range of junior and senior students (N = 28)[3]—some of whom were also teaching fellows—were selected for their strong academic involvement in each program, their capacity to reflect about learning, and their varied disciplinary backgrounds. Faculty and administrators were asked to select samples of interdisciplinary student work ranging in quality, genre, and subject matter. The selection of students and work was not limited to the courses taught by the faculty in our sample; nine pieces were by students who were interviewed.

In total, data for this study consisted of 69 interviews, 10 classroom observations, 40 samples of student work, and assorted program documentation. Two researchers conducted in-depth, semistructured interviews of 1–1.5 hours with faculty and students. The interview covered aspects of pedagogy and learning, with a considerable portion dedicated to assessment. For example, faculty were asked to describe their assessment strategies in general and the qualities they look for in student interdisciplinary work in particular. All faculty interviews were fully transcribed. Student interviews, considered primarily as background information in this analysis, were selectively transcribed to capture sections relevant to assessment. Classroom observations provided context to claims made by our informants.

An initial content analysis of transcripts yielded features that faculty associated with quality student interdisciplinary work, whether in describing exemplary pieces, characterizing learning goals, or listing the criteria by which they assessed student outcomes. Qualities of work valued by faculty were initially grouped under seven core categories (i.e., effective integration of different disciplines, incorporating multiple perspectives and different voices, critical and/or logical thinking, writing standards, respect for disciplinary standards, originality and creation of new knowledge, substantiated and grounded work).We focused our analysis on faculty's *epistemic characterizations* of student work (37 transcripts). We bracketed generic references to habits of work and personal relevance embodied in claims such as "I get excited when I see a student [doing something that] they've always wanted to do it, now they can do it" or "one standard is that they show up, that they actually are engaged in the process, week by week." While often valuable, these traits are not specific to interdisciplinary work.

Pragmatic constructivist epistemology (Elgin, 1996, 1997; Goodman, 1978) informed the further articulation of a classification scheme by providing four orienting principles on the epistemology of knowledge validation: A piece of work is deemed (a) *acceptable* according to its epistemic function (e.g., to explain a phenomenon, express something artistically); (b) *credible* by the degree to which it echoes previously

established norms and understandings; (c) *relevant* when it expands productively beyond prior knowledge; and (d) *provisional* in that it is subject to ongoing critique that determines its acceptability.

These principles informed our grouping of faculty descriptors; in turn, faculty descriptors provided substance to otherwise generic epistemic principles, tailoring the emerging framework to the unique challenges of assessing *interdisciplinary* work. For example, the principle of *credibility* enabled us to merge faculty comments associated with two initial categories—"respect for disciplinary standards" and "substantiated and grounded work"—under a category that highlighted a piece of work's grounding in established disciplinary knowledge and modes of thinking. In turn, faculty comments shed light on the challenge of "grounding" work in two or more sometimes conflicting disciplinary traditions—a demand unique to interdisciplinary work.

Our emerging framework was refined through close application to 40 samples of student work. Two researchers assessed a selection of student products jointly (N = 8), occasionally drawing on course bibliographies or student and faculty interviews as background. Discussions of these cases yielded modifications to the framework—for example, a dimension specifically addressing the "genre" of the work was eliminated to avoid redundancy in the model and to sharpen its focus on *interdisciplinary* rather than generic student work. Analytical memos examining student work were discussed by our research group in search for potential contradictions, conceptual overlaps, and redundancy.[4] Student interview data was used to gather additional supporting and disconfirming claims.

Given our analytical approach, the resulting framework is descriptive insofar as the criteria were initially derived from our data. It is conceptual in the sense that it builds on a constructivist epistemological tradition that enabled us to group faculty claims into a coherent whole. It is normative in that it is designed to serve as a usable foundational tool to assess and promote interdisciplinary understanding beyond our sample.

Results: Toward a Framework for Assessing Students' Interdisciplinary Work

Faculty members were eloquent about the specific qualities and advantages of interdisciplinary work when discussing pedagogical aims and individual pieces of student work. However, they consistently met explicit questions about assessing interdisciplinary work with doubt and self-criticism. Most referred initially to the *process* by which they assessed student understanding, such as presenting real-life problems or collecting portfolios of work. Yet, when pressed to address the *substance* of their assess-

ment—that is, what they viewed as the markers of a good piece of interdisciplinary work—faculty expressed unease and said they would welcome guidance. Their shift to metaphoric language—for example, "when it all clicks together"—often revealed the lack of a conceptual language to refer systematically to core qualities of interdisciplinary work. Confirming this perception, the informants' reported grading practices often combined generic qualities such as "logic of argument" and "quality of writing" with dispositional criteria like students' "effort" and "commitment."

Building on our analysis of interviews and student work and in conjunction with the epistemic principles described above, the emerging assessment framework highlights three core dimensions of students' interdisciplinary work:

1. The degree to which student work is *grounded* in carefully selected and adequately employed disciplinary insights—that is, disciplinary theories, findings, examples, methods, validation criteria, genres, and forms of communication.
2. The degree to which disciplinary insights are clearly *integrated* so as to advance student understanding—that is, using integrative devices such as conceptual frameworks, graphic representations, models, metaphors, complex explanations, or solutions that result in more complex, effective, empirically grounded, or comprehensive accounts or products.
3. The degree to which the work exhibits a clear sense of purpose, reflectiveness, and self-critique—that is, framing problems in ways that invite interdisciplinary approaches and exhibiting awareness of distinct disciplinary contributions, how the overall integration "works," and the limitations of the integration.

These three dimensions—*disciplinary grounding*, *advancement through integration*, and *critical awareness* (see Figure 1)—organize our presentation of faculty views of quality interdisciplinary work and the assessment challenges that they encountered.

I. Disciplinary Grounding

Among the instructors addressing epistemic qualities of student work in our study, most (75%) felt that strong disciplinary grounding was necessary to produce work of quality. As Bruce Grant (IT) and David Magnus (BioE) put it, a rigorous disciplinary grounding diminishes the risk of interdisciplinary courses being "a mile wide and an inch deep" or "a light educational experience."

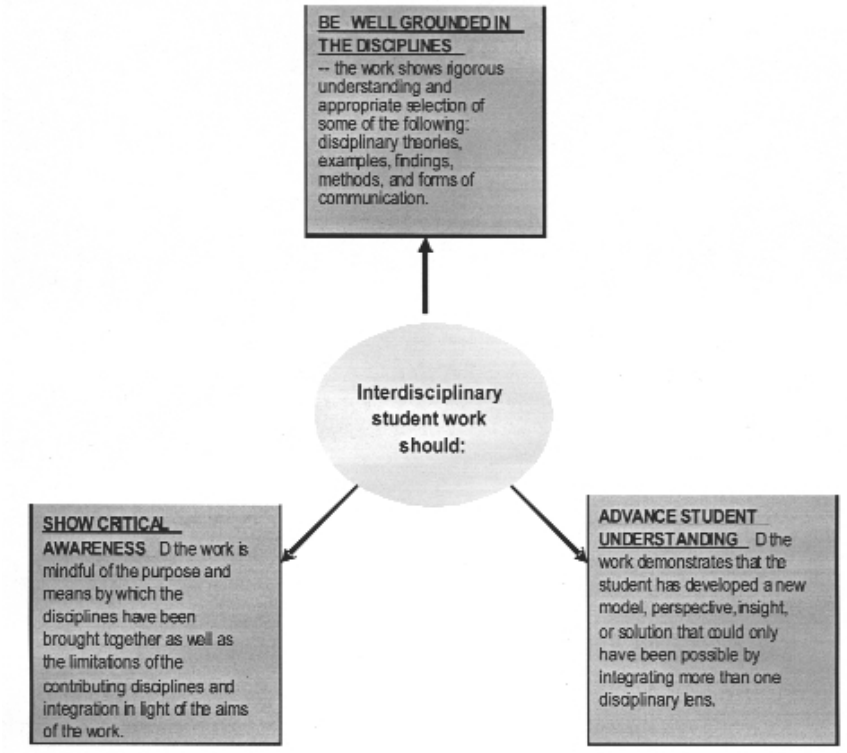


FIG. 1. Three interrelated criteria for assessing students' interdisciplinary work.

In some courses students were assessed on basic content first because thorough understanding of disciplinary concepts or methods was seen as a prerequisite for effective interdisciplinary work. "If they [students] don't have the basic understanding, they can't draw the links," commented Amy Perfors, a Hum Bio teaching assistant. This practice seemed particularly prevalent in "vertical domains," such as physics or chemistry, where learning paths are relatively structured and incremental (Li, 1997). Courses in the humanities offered at IT tended to propose making connections from the beginning across what several viewed as permeable disciplinary borders. Yet, according to most faculty, such connections did not happen at the expense of disciplinary thoroughness: One faculty member commented that many "students are very anxious to be interdisciplinary often before they understand what the different disciplines are. . . . I want the students to have . . . at least provisional grounding or understanding of what it means to be grounded."

Two dissident voices at IT characterized disciplinary inquiry as unduly emphasized and empowered in higher education. For example, one asked, "Why is it necessary, if you're going to say something that's significant, [that] it emanates from some kind of discipline? In fact, one might even pose the possibility that in the long run disciplines are injurious." However, while the rest of the faculty we interviewed commonly referred to the departmental organization of higher education as stifling, they did not seem to question the epistemic value of disciplinary insights, often offering a dynamic view of disciplines and their work. As Robert Siegel at Hum Bio put it, "[Disciplines] are things that we create. . . . they're mobile things."

If students were drawing from multiple disciplines, our informants claimed, it was unreasonable and unnecessary to expect them to "master" all the disciplines involved. Assessing student work thus involved considering how students selected some disciplines and insights over others, such as particular theories, methods, tools, and forms of communication. In Magnus's view, interdisciplinary integration should be driven by the problems that we mean to tackle rather than be pursued for its own sake: "They [students] have to know enough of the things that you would know from each of those disciplines to be able to do interesting, important work."

The demands of "disciplinary grounding." While clearly desirable, assessing the disciplinary foundations of students' work is not always easy. When probed, faculty puzzled over which aspect of each constituent discipline was to be assessed (e.g., accurate representation of events or ability to interpret primary sources). Some faculty expressed concern about dogmatic views of disciplinary practices where methodology and accepted hypotheses are presented as definite and fixed, or with students who equate disciplinary knowledge with "information." On the other hand, faculty were also concerned about students who focus too heavily on methodological reflection. They described the danger of students going "meta" too quickly by focusing on epistemology and methodology at the expense of more substantive disciplinary understanding. As Perfors remarked, "The meta questions do not make a lot of sense if you are not understanding the material that they are about."

Faculty also recognized that unlike their disciplinary counterparts, the products of interdisciplinary work should connect with multiple—often conflicting—disciplinary audiences. In the view of NEXA instructor Ellen Peel, students must learn to communicate their disciplinary knowledge to a wider audience and to facilitate dialogue among people who do not speak the same language. Arthur Caplan, director of BioE, claimed,

"[Bioethics students] have to understand that they are going to need to pitch an answer in a term or phrase or a presentation that works [for the particular audience]."

"Disciplinary grounding" defined. This analysis suggests that assessing interdisciplinary work involves carefully considering its disciplinary grounding by a focus on *selection* (of disciplines and insights) and *appropriateness* (in the use of knowledge and modes of thinking). Are the selected disciplinary insights fit to inform the issue at hand? Are any key disciplinary perspectives missing? Are the considered theories, examples, findings, methods, and forms of communication employed in accordance with their disciplinary origins, or does the work exhibit misconceptions? Close disciplinary reading of student work should unearth the foundational bodies of expertise on which a piece stands. Targeted and informative feedback then becomes possible.

II. Advancement through integration

Arguably all student work, interdisciplinary or otherwise, is (or should be) aimed at advancing student understanding. IT's Timothy Burke, for example, valued student work that "pushes the boundaries." What interested him, he claimed, "significantly involves not sending back to me something I already said. . . . [T]he end goal is never the reproduction of my own practice." In this sense, like most exemplary educators at the secondary and tertiary levels, the faculty in our sample seemed to embrace understanding—that is, the capacity to use knowledge flexibly—as the purpose of their educational efforts. They were less interested in the accumulation of information than the capacity to think with the information at hand when confronted with novel situations.

In interdisciplinary work, students advance their understanding by moving to a new conceptual model, explanation, insight, or solution. To do so, they employ the unique advantages afforded by bringing together more than one disciplinary lens. Sixty eight percent of the faculty addressing epistemic qualities of student work identified "synthesis" or "integration" as an essential feature of interdisciplinary work, often in association with innovation. For instance, Burke described the best interdisciplinary work as taking "a tool set from one discipline and very rigorously and thoroughly applying it in a place where its application was not invited or anticipated." Perfors commented, "Human Biology really emphasize[s] synthesizing and bringing in many points of view on the same problem." Caplan stated that bioethics involves "using different skills, different approaches to solve a problem."

Student Vail Miller (BioE) described how understanding is advanced by combining disciplinary lenses. When asked to describe a good

bioethics student, she contrasted a scientist working on leukemia in a strict molecular way with a philosopher pondering the ethics of leukemia treatment at a highly abstract level. She thought a good bioethics student should "synthesize those two modes of thinking." She claimed that understanding law and ethics can "add the human element" often missed by scientists, while appreciating the practical implications of legislative and moral decisions requires "hard knowledge of the science"; for instance, arguments about whether to keep patients in a persistent vegetative state alive should be informed by what neurologists know about the condition.

However, this assertion does not imply that the different disciplines used in bioethics—or in any other interdisciplinary endeavor—are always equally represented in a piece of work; perspectives must be balanced in a thoughtful way relative to the purpose of the piece. Caplan described how the bioethical issue at hand should determine whether law and philosophy, for example, are accorded more or less importance:

> For certain issues you do want to know what really is the legal framework that you're operating in. And for some issues like "Should we ban cloning?" starting with the law is really not a good idea. For those, you really need to think philosophically about what cloning is and why it would be bad.

In our examination of student work, its synthetic quality typically became visible as students employed integrative devices—that is, epistemic frames that enabled them to articulate two or more disciplinary understandings. Some students used *complex explanations*, integrating causes stemming from various disciplines to account for a complex phenomenon. For example, NEXA students explained the impact of the nuclear revolution by interweaving their scientific understanding of atomic energy with an analysis of the relevant historical and sociological context. *Aesthetic reinterpretations* enabled other NEXA students to synthesize their responses to literary and musical interpretations of the Faust legend; for example, exploring the role of religious symbolism through an installation or painting. Bioethics students framed their integration as a *practical solution* that borrowed strategically from different disciplines to craft a viable and coherent way to address a defined problem, such as a shortage of donated organs. Integrative framing devices may take the form of conceptual frameworks, graphic representations, models, leading metaphors, complex explanations, or solutions to a problem. These devices play a key role in the construction of a coherent integration among elements stemming from different disciplinary traditions.

The demands of integration. Determining the degree to which students' understanding has been advanced by interdisciplinary work pre-

sented faculty with predictable challenges. For instance, some informants referred to the difficulty of assessing innovation: What might be perceived as original in one discipline might be common practice in another. Some also addressed the problem of assessing individual students' new insights, given the diversity of backgrounds and skills that they bring to tasks. However, the greatest challenge concerning assessment involved a precise articulation of how understanding is advanced by the combination and balance of views—that is, pinpointing the value added by the integration of disciplines.

While only a handful of informants offered an explicit articulation of the advances in understanding stemming from the merging of disciplinary views, our analysis of student work yielded a repertoire of examples of new models, insights, or solutions that could not have been arrived at through a single discipline. Tess Bridgeman, a student in Hum Bio, investigated the high incidence of neural tube birth defects in Oaxaca, southern Mexico, caused largely by a lack of folic acid in women's diets. Her work moved beyond a strictly medical perspective to include a consideration of the social and economic contexts surrounding these women's lives:

> You can trace back a chain of causes to look at the whole context of what it is that is going on. You start from a health concern but you end up talking about government priorities or international trade issues or agriculture. All of these things are really inter-related.

Recognizing that women could not afford prenatal vitamins, she identified an indigenous grain rich in folic acid and worked with a nongovernmental organization to set up a program for reintroducing it into the local diet. The integration and balance of insights from political science, economics, and agriculture afforded Bridgeman a complex understanding of the problem, enabling her to propose a novel and viable solution.

Advancement through integration defined. It follows that assessing the integrative qualities of a piece of work involves identifying points of disciplinary integration and articulating the cognitive advantage enabled by the combination of perspectives. Key questions include: (a) Where is there evidence of disciplinary integration (e.g., conceptual framework, graphic representation, model, leading metaphor, complex explanation, or solution to a problem)? (b) Is there evidence that understanding of the issue under study has been enriched by the integration of different disciplinary insights, (e.g., yielding a comprehensive explanation, a more viable solution)? (c) What would be lost if a particular disciplinary insight were missing from the work or if the balance of disciplinary insights were different? Articulating how understanding is advanced by discipli-

nary integration amounts to unpacking the "magic" of interdisciplinary insights. It entails characterizing the specific ways in which the whole of the understanding is more than the sum of its disciplinary parts.

III. Critical Awareness

Fifty four percent of the faculty in our study who addressed epistemic qualities of student work called for a reflective stance among their students. Exemplary student work weighs the benefits of one disciplinary perspective against those of another and against the overall purpose of the enterprise; a student's integration is always subject to revision and critique, allowing room for constructive adjustments and retooling. While individual faculty described this process of consideration only in partial terms, many of them recognized the vital role played by a metadisciplinary and critical stance in quality interdisciplinary work. In sum, assessing students' work involves examining the degree to which students were reflective about the purpose of their work, the means by which goals were reached, and the limitations of their work.

The demands of "critical awareness." Disciplinary coordination, many informants claimed, imposes important cognitive demands on students. It requires, for example, that students develop a sense of their work at a metadisciplinary level, that they identify disciplinary blind spots, consider opportunities for integration, navigate methodological differences, and choose among competing units of analysis. As Magnus suggested, the success of integrative efforts must be measured against the goals guiding the enterprise as a whole, and faculty valued work that exhibited clarity of purpose. IT philosopher Richard Eldridge stated that he looked for students' "control of the stakes of the issue: why the issue matters, what stances were available, and what might make them interesting." Students must keep the goals of their work in sight as they navigate the complexities of integration; in turn, this helps them to gauge more clearly the successes, compromises, and limitations of their integration. Such a "meta" coordination of perspectives seemed not only a natural dimension of interdisciplinary learning but also an indicator of quality interdisciplinary work.

"Critical awareness" defined. The third dimension of our assessment framework, *critical awareness*, sheds light on the degree to which a piece of work exhibits clarity of purpose and offers evidence of reflective self-critique. (a) Does a piece of student work show clear goals, framing the issue in ways that invite an interdisciplinary approach? (b) Does the work exhibit reflectiveness about the choices, opportunities, compromises, and limitations that characterize interdisciplinary work and about the limitations of the work as a whole, such as what an account failed to explain or what a solution could not address? Producing

interdisciplinary work of quality demands that students engage in a process of considered judgment—weighing options and making compromises to achieve their proposed aims. This dimension focuses faculties' attention on such judgments using the student's stated *purpose* as a guide to assess his or her reasoning and choices.

The Targeted Assessment Framework emerging from our work focuses attention on three core dimensions of student work. First, it addresses the degree to which a piece of interdisciplinary work builds on strong disciplinary foundations—that is, whether there is an appropriate selection of disciplinary perspectives and whether disciplinary knowledge and modes of thinking are employed rigorously. Second, the framework calls for an articulation of the degree to which the integration of disciplines is advancing student understanding in relation to the purpose of the work, such as yielding new practical solutions or deepening explanations. Third, the framework examines students' clarity about their understanding purpose and the means and limitations of their efforts. Appendix C offers a summary of key criteria and guiding assessment questions, and Appendix D illustrates how the framework can be applied to a piece of student work.

Conclusion: The Assessment Framework in Practice

The literature on interdisciplinary instruction has presented faculty with various taxonomies of interdisciplinarity. Descriptors such as (but not limited to) "multi-," "inter-," or "transdisciplinary" (Klein & Newell, 1998; Lattuca, 2001; Newell 2001, 2002) have been used to characterize levels of integration in response to the question, "How interdisciplinary is a particular piece of work?" Broadly adopted, even if only partially understood, such categorizations have tended to associate *quality work* with *greater* integration (typically the domain of "transdisciplinary" work). In the educational literature, the "blending" or indistinguishable merging of disciplinary inputs is viewed as somehow more advanced than integrations where disciplinary articulations are visible or in which disciplinary work is expanded in small scale interdisciplinary combinations (e.g., Burns, 1995; Clarke & Russell, 1997).

Our framework seeks to move beyond such definitional debates and characterizations. It stems from the understanding that no single characterization of "levels of integration" can discriminate between accomplished and novice interdisciplinary work. Instead, we propose that the *success* of an integration be measured by the degree to which it achieves its purpose—a more comprehensive account, a new legal amendment, an empirically grounded argument, a more generalizable model. In these contexts, the essential question to assess interdisciplinary work is not

"How much integration is enough?" but "What is the cognitive and practical *purpose* of this work, and is this integration advancing it in disciplinary grounded and reflective ways?" Program evaluators may similarly cease to ask "how interdisciplinary" an educational initiative is but "how effective" it is in producing quality learning among its students as measured by close analysis of student work and student competencies. To this end, the proposed framework provides a common language for faculty across disciplines and fields to describe particular qualities of student interdisciplinary work—crucial for creating a *culture* of quality interdisciplinary teaching in our educational institutions.

A productive use of the framework demands first a careful adaptation of each of its dimensions to the problems of study and disciplinary repertoires in a particular course or program. What are the disciplinary understandings that the course sought to develop? What should be the value added by bringing disciplinary lenses together? How might students exhibit critical awareness in this particular project? Questions of this kind enable instructors to tailor the framework to their content areas and to take into account the aims and processes of their instruction.

A second practical consideration pertains to the selection of student work to be assessed. The framework is designed to shed light on multiple kinds of student performances (e.g., papers, videos, presentations, works of art). Yet, clearly, the genre of a particular piece of work largely defines which aspects of understanding are made visible. Some genres (e.g., an academic paper) may invite explicit *critical awareness* whereas others (e.g., a short story) may not. An accomplished work of art, for example, will invite multiple interpretations on the part of the viewer. Unpacking its disciplinary foundations explicitly can immediately limit its aesthetic power. In such cases, additional pieces of student work (e.g., other papers, a reflective memo) will make student learning visible for feedback and evaluation.

Whether through the creation of an assessment rubric or as a tool to support student self-assessment, the framework emerging from our analysis enables instructors to articulate desired qualities in student understanding, such as the use of integrative devices to bring disciplinary insights together in coherent and effective ways. Conversely, it helps them identify common pitfalls and misconceptions to be avoided. Examples of these include, but are not limited to, a piece of work's attempt to include "all disciplines" (compromising the principle of selectivity); an unproductive integration (which brings perspectives together but does not advance the desired understanding); an overemphasis on reflectivity characterized by extensive use of integrative language that is not accompanied by substantive understanding.

In sum, by shedding light on qualities of interdisciplinary understanding, the framework informs how faculty set learning objectives and standards, and it enables them to provide students with informative feedback throughout a course.

APPENDIX A
Overview of Course Sample

Program	Mission	Features
Bioethics at the University of Pennsylvania [BioE] (previously a major; now a concentration)	Addresses the ethical, legal, social, and public policy implications of scientific and medical advances; fosters communication between scientists, philosophers, and general public.	Center is an interdisciplinary unit of the School of Medicine; solo teaching by faculty with diverse disciplinary backgrounds.
Interpretation Theory at Swarthmore [IT] (minor)	Focuses on critical and cultural theory; broadly includes the nature and politics of representation across the disciplines.	Most courses were team-taught (no longer the case); students required to take a range of courses to gain breadth, depth, and different disciplinary perspectives; final capstone seminar required.
Human Biology at Stanford University [Hum Bio] (major or minor)	Seeks to understand the human being from biological, behavioral, social, and cultural perspectives; applies this understanding to formulate and evaluate public policy.	A year long core course sequences themes examined jointly by the natural and social sciences "sides" of the course. Students choose an area of concentration and write a final thesis.
NEXA Program at San Francisco State University [NEXA] (concentration in Liberal Studies major, minor, courses approved for General Education)	Aims to bridge the divide between the humanities and sciences by focusing on reciprocal relationship between scientific development and cultural values; also includes integrated literature and music courses.	Courses are team-taught; program promotes idea of "convergence"—i.e. different disciplines coming together to shed light on a common theme.

APPENDIX B

Overview of Faculty Sample

Program and number of faculty interviewed	Informant	Main stated disciplinary affiliation of informant	Examples of combinations of disciplines and fields involved in courses taught
Bioethics, University of Pennsylvania [BioE] N = 6	XUP01	anthropology/communications	Sociology, ethics, medicine
	XUP02	history/philosophy	Philosophy, law, sociology, medicine,
	XUP03	sociology	Medicine, sociology
	XUP04	philosophy	Philosophy, medicine, law
	XUP05	sociology	Sociology, medicine, Judaic studies, ethics
	XUP06	philosophy	Philosophy, law, sociology, medicine
Interpretation Theory, Swarthmore College [IT] N = 9	XSWA01	history	(African)history and cultural theory
	XSWA02	engineering	Computer science and literary theory
	XSWA03	theology	Literature and theology
	XSWA04	sociology	Sociology and English literature
	XSWA05	biology	Biology and cultural theory
	XSWA06	philosophy	Philosophy of art and art historiography
	XSWA07	French literature	Biology and cultural theory
	XSWA08	psychology	Psychology and cultural theory
	XSWA10	anthropology/sociology	Anthropology and film studies
Human Biology, Stanford University [Hum Bio] N = 12	XST04	health policy	Health policy and sociology
	XST07	neuroscience	Neuroscience, anthropology, sociology
	XST08	psychology/epidemiology	Clinical sciences, psychology, sociology
	XST09	psychology/biology	Biology, medicine, epidemiology, psychology
	XST10	political science	Environmental policy and law
	XST11	ecology	Genetics, evolutionary biology, ecology, policy
	XST12	anthropology/biology	Genetics, evolutionary biology, ecology, policy
	XST13	anthropology/social theory	Social theory, genetics, ecology, biology
	XST14	developmental psychology	Psychology, anthropology
	XST16	biology	Env. science, medicine, policy
	XST17	medicine/ethics	Biology, medicine, ethics
	XST18	biology	Biology, medicine, sociology

APPENDIX C

Summary of Key Criteria and Guiding Assessment Questions

Criteria	Guiding Questions
I. Disciplinary grounding	Are the selected disciplines appropriate to inform the issue at hand? Are any key perspectives or disciplinary insights missing?
	Are the considered disciplinary theories, examples, findings, methods, and forms of communication accurately employed, or does the work exhibit misconceptions?
II. Advancement through integration	Where is there evidence of disciplinary integration (e.g., conceptual framework, graphic representation, model, leading metaphor, complex explanation, or solution to a problem)?
	Is there evidence that understanding has been enriched by the integration of different disciplinary insights?
III. Critical awareness	Does the work show a clear sense of purpose, framing the issue in ways that invite an interdisciplinary approach?
	Is there evidence of reflectiveness about the choices, opportunities, compromises, and limitations involved in interdisciplinary work and about the limitations of the work as a whole?

APPENDIX D

Applying the Criteria to an Example of Student Work

Vail Miller's Argument for Permitting Anencephalic Organ Donation

Miller's piece on infant organ donation was the final assignment for the course "Controversial Issues in Bioethics" taught by philosopher Glenn McGee at BioE. The assignment asked students to propose and draft legislative change related to a bioethical issue. Miller opens her paper with the scene of a couple learning that their newborn baby will die of Hypoplastic Left Heart Syndrome (HPLS) within a year. She outlines the medical condition for which the only reliable cure is heart transplantation. Next she introduces anencephaly, "the most common severe birth defect of the central nervous system seen in the United States" (p. 1). Anencephaly, the absence of a skull and upper brain, is always terminal. She then points out that in the U.S. the number of anencephalic infants born of adequate size for organ donation matches the number of babies born with HPLS. However, because organs need to be removed from anencephalics before they are officially dead, these cases of organ donation are legally impossible in most states.

APPENDIX D (*Continued*)

Applying the Criteria to an Example of Student Work

Vail Miller's Argument for Permitting Anencephalic Organ Donation

Miller proposes a solution: "a redefinition of 'death' applying only to humans born with anencephaly, to make more donor hearts available to brain-normal infants dying of HPLS" (p. 2). She cites the legal history to date on the matter, such as the first statute on the definition of death passed in Kansas in 1970, and refers to a case where parents were prevented from donating the organs of their anencephalic child Theresa. She then describes current treatments for HPLS in detail and the complex procedures involved in staged heart reconstruction. Despite the risks and lifelong need for immunosuppressant drugs, transplantation provides the best outlook for these children at present. Miller cites the example of Baby Gabriel at Loma Linda University, who in 1987 became the first anencephalic heart donor "to a recipient who survived and went home and thrived" (p. 3). Gabriel's organs were kept healthy by the intubating of oxygen until he was declared dead as a result of permanent brain dysfunction. Other transplants of this kind were not successful because "the organs had undergone irreversible hypoxic injury during the process of dying and had become unsuitable for donation by the time of whole brain death" (p. 4).

Miller believes the scientific community would view anencephalics as dead at birth because they have no brain waves or any form of consciousness. She thinks that many parents of both recipients and donors would welcome a change in the law, the latter to "give their child's life a purpose" (p. 4). She cites a Florida newspaper where overwhelming support was expressed for Baby Theresa's parents and sees this as indicative of general public support for a shift in legislation. Miller warns her readers that her proposed legislative change should not refer to any other medical conditions, such as persistent vegetative state, because not enough is known about them. In contrast, she believes that anencephaly is an unambiguous condition and that legislative provision should facilitate infant organ donation. In her piece of draft legislation, she calls for the Determination of Death Act in Pennsylvania to be amended so that anencephalic infants can be classified as dead and their organs more easily donated.

Disciplinary grounding

Selection: Law and medicine were appropriate choices to inform Miller's goals; psychology and/or religion could also have been relevant (e.g., to consider if parents are likely to embrace the legal change proposed). *Use of disciplines: (1) Law*. She accurately described legal precedents, showed awareness of factors shaping legislation and the legal process, and produced a piece of legal discourse. *(2) Medicine.* She appropriately used information about conditions/treatments but did not consider different expert opinions or the tentative nature of medical knowledge.

Advancement through integration

Miller's solution depended on both medicine and law: Legal analysis led to a plausible solution to a medical problem (i.e., a lack of donor hearts), while medical understanding highlighted the law's inability to account for anencephaly.

Critical awareness

Purpose: She showed a clear sense of purpose that invited an interdisciplinary approach—that is, to save babies' lives. *Self-critique:* No rationale was given for her disciplinary choices and there was no discussion of the limitations of her solution—for example, that legislation might not lead to change if parents are unreceptive to it.

Notes

[1]Lattuca, Voigt, and Fath (2004) Lindholm et al. (2002), a 2001–2002 survey in which nearly 40% of faculty reported having taught an interdisciplinary course.

[2]Our definition coincides with the one recently proposed by the National Academies, which, focusing on interdisciplinary research, posits that: "Interdisciplinary research (IDR) is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice" (2005, p. 2).

[3]BioE, N = 5; IT, N = 8; Hum Bio, N = 7; NEXA, N = 8; teaching fellows at Hum Bio (N = 4) were recent graduates of the program.

[4]Researchers in the team represent areas of expertise that include sociology, English, cognitive developmental psychology, epistemology, history, music, dance, as well as science/history and art education.

References

Astin, A.W. (1985). *Achieving educational excellence*. San Francisco: Jossey-Bass.

Astin, A. W. (1993). *Assessment for excellence: The philosophy and practice of assessment and evaluation in higher education*. Phoenix, AZ: Oryx.

Banta, T. W. (Ed.). (2002). *Building a scholarship of assessment*. San Francisco: Jossey-Bass.

Boix Mansilla, V. (2005). Assessing student work at disciplinary crossroads. *Change Magazine 37.* 1, 14–21.

Boix Mansilla, V. (2006). Quality assessment of interdisciplinary research: Toward empirically grounded validation criteria. *Research Evaluation*.

Boix Mansilla, V. & Gardner, H. (1999). What are the Qualities of Understanding? In S. Wiske (Ed.), *Teaching for understanding: A practical framework*. San Francisco: Jossey-Bass.

Boix Mansilla, V., & Gardner, H. (2000). On disciplinary lenses and interdisciplinary work. In S. Wineburg & P. Grossman (Eds.), *Interdisciplinary curriculum challenges of implementation* (pp. 161–198). New York: TC Press.

Boix Mansilla, V., & Gardner H. (2003). Assessing interdisciplinary work at the frontier: An empirical exploration of "symptoms"of quality. Retrieved from *www.Interdisciplines.org*

Boix Mansilla, V., Miller, W. C., & Gardner, H. (2000). On disciplinary lenses and interdisciplinary work. In S. Wineburg & P. Grossman (Eds.), *Interdisciplinary curriculum: challenges to implementation.* (pp. 17–38). New York: Teachers College Press.

Burns, R. C. (1995). *Dissolving the boundaries: Planning for curriculum integration in middle and secondary schools*. Charleston, WV: Appalachia Educational Laboratory.

Clarke, J., & Russell, A. (Eds.) (1997). *Interdisciplinary high school teaching: Strategies for integrated learning.* Boston: Allyn and Bacon.

Elgin, C. Z. (1996). *Considered judgment*. Princeton, NJ: Princeton University Press.

Elgin, C. Z. (1997). *Between the absolute and the arbitrary*. Ithaca, NY: Cornell University Press.

Ewell, P. T. (1984). *The self-regarding institution: Information for excellence*. Boulder, CO: National Center for Higher Education Management Systems.

Ewell, P. T. (1991). To capture the ineffable: New forms of assessment in higher education. *Review of Research in Education, 17,* 75–125.

Field, M., Lee, R., & Field, M. L. (1994). Assessing interdisciplinary learning. In J. T. Klein & W. G. Doty (Eds.), *Interdisciplinary studies today* (pp. 69–84). San Francisco: Jossey-Bass.

Field, M., & Stowe, D. (2002). Transforming interdisciplinary teaching and learning through assessment. In C. Haynes (Ed.), *Innovations in interdisciplinary teaching* (pp. 256–74). Westport, CT: American Council on Education Oryx Press.

Gardner, H., & Boix Mansilla V. (1994). Teaching for understanding in the disciplines and beyond. *Teachers College Record.* (Winter-1994), 198–218.

Goodman, N. (1978). *Ways of worldmaking*. Indianapolis, IN: Hackett.

Haynes, C. (Ed.). (2002). *Innovations in interdisciplinary teaching*. Westport, CT: Oryx Press.

Hutchings, P. (1990). Learning over time: Portfolio assessment. *American Association of Higher Education Bulletin, 42,* 6–8.

Jacob, H. H. (2002). Integrated curriculum design. In J. T. Klein (Ed.), *Interdisciplinary education in K-12 and college* (pp. 23–43). New York: College Board Publications.

Kavalovsky, V. C. (1979). Interdisciplinary education and humanistic aspiration. In J. J. Kockelmans (Ed.), *Interdisciplinarity and higher education* (pp. 224–43). University Park, PA: Pennsylvania State University Press.

Klein, J. T. (2000). A conceptual vocabulary of interdisciplinary science. In P. Weingart & N. Stehr (Eds.), *Practising interdisciplinarity* (pp. 3–24). Toronto: University of Toronto Press.

Klein, J. T. (2002). Assessing interdisciplinary learning K-16. In J. T. Klein (Ed.), *Interdisciplinary education in K-12 and college* (pp. 179–96). New York: College Board Publications.

Klein, J. T., & Newell, W. (1998). Advancing interdisciplinary studies. In W. Newell (Ed.), *Interdisciplinary essays from the literature* (pp. 3–22). New York: College Board Publications.

Lageman, E. C. (2002). *Usable knowledge in education: A memorandum for the Spencer Foundation Board of Directors*. Retrieved June 15, 2005, from http://www.spencer.org/publications

Lattuca, L. R. (2001). *Creating interdisciplinarity: Interdisciplinary research and teaching among college and university faculty*. Nashville, TN: Vanderbilt University Press.

Lattuca, L. R., Voigt, L. J. & Fath, K. Q. (2004). Does interdisciplinarity promote learning? Theoretical support and researchable questions. *The Review of Higher Education, 28* (1), 23–48.

Li, J. (1997). Creativity in horizontal and vertical domains. *Creativity Research Journal, 10,* 107–132.

Lindholm, J. A., Astin, A. W., Sax, L. J., & Korn, W. S. (2002). *The American college teacher: National norms for the 2001–02 HERI faculty survey.* Los Angeles: Higher Education Research Institute.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies. (2005). *Facilitating interdisciplinary research*. Washington, DC: The National Academies Press.

Newell, W. (1998). Interdisciplinary curriculum development. In *Interdisciplinarity: Essays from the literature* (pp. 51–65). New York: College Board Publications.

Newell, W. (2001). A theory of interdisciplinary studies. *Issues in Integrative Studies, 19,* 1–25.

Newell, W. (2002). Integrating the college curriculum. In J. T. Klein (Ed.), *Interdisciplinary education in K-12 and college* (pp. 119–37). New York: College Board Publications.

Newell, W., & Green, W. J. (1982/1998). Defining and teaching interdisciplinary studies. In W. Newell (Ed.) *Interdisciplinarity: Essays from the literature*. (pp. 23–30). New York: College Board Publications.

Perkins, D. (1998). What is understanding? In M. S. Wiske (Ed.), *Teaching for understanding: Linking research with practice* (pp. 39–57). San Francisco: Jossey-Bass.

Schilling, K. L. (2001). Interdisciplinary assessment for interdisciplinary programs. In B. L. Smith & J. McCann (Eds.), *Reinventing ourselves: Interdisciplinary education, collaborative learning and experimentation in higher education* (pp. 344–54). Bolton, MA: Anker.

Seabury, M. B. (1999). *Interdisciplinary general education: Questioning outside the lines*. New York: College Entrance Examination Board.

Shulman, L. S. (2004) *The wisdom of practice: Essays on teaching, learning, and learning to teach*. San Francisco: Jossey-Bass.

Shulman, L. S. (1987). Assessment for teaching: An initiative for the profession. *Phi Delta Kappan, 69* (1).

Smith, B. L., & McCann J. M. (2001). *Reinventing ourselves: Interdisciplinary education, collaborative learning, and experimentation in higher education*. Bolton, MA: Anker.

Stowe, D., & Eder, D. (2002). Interdisciplinary program assessment. *Issues in Integrative Studies, 20,* 77–101.

Wiggins, G. (1998). *Educative assessment*. San Francisco: Jossey-Bass.

Wolfe, C. R., & Haynes, C. (2003a). Assessing interdisciplinary writing. *Peer Review, 6*(1), 12–15.

Wolfe, C. R., & Haynes, C. (2003b). Interdisciplinary writing assessment profiles. *Issues in Integrative Studies, 21,* 126–69.

Copyright of Journal of Higher Education is the property of Ohio State University Press and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.