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INTERDISCIPLINARY INTEGRATION BY UNDERGRADUATES

by

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Abstract: This article examines whether it is feasible to teach interdisciplinary integration to undergraduates, especially the demanding conception of integration envisioned in my "A Theory of Interdisciplinary Studies." The 37 senior projects completed in the spring of 2005 in the Western College Program at Miami University are analyzed for each of the integrative steps in my latest version of the interdisciplinary process: identifying, illuminating, and evaluating conflict in insights; constructing common ground; identifying linkages among disciplines; constructing/modeling a more comprehensive understanding; and testing the new understanding. Numerous examples of the successful implementation of each step are presented. The entire set of projects is then evaluated using the interdisciplinary integration profile from the Wolfe-Haynes assessment instrument to determine how many of the integrative steps set out in that instrument were completed by these seniors and how well the steps were carried out. The article also examines whether the academically most successful students achieved more complete or higher quality integration.

One of the charges leveled at the theory of interdisciplinary studies advanced in Newell (2001) is that its conception of integration is too difficult to teach to undergraduates, if not too difficult for senior faculty to master. In his critique of that theory, J. Linn Mackey (2001) likens its conception of the interdisciplinarian to a "heroic" modeler, asserting that its conception of interdisciplinary study "paints an inflated and unrealistic picture of what the interdisciplinary scholar does." He says, "I do not believe any empirical study of interdisciplinary knowledge production would show it operates that way. A Newton, Darwin, or Marx appears rarely." Instead he sees "interdisciplinary scholarship as much like that of a scholar adding a new interpretation to Franklin's autobiography. Interdisciplinary scholarship does not usually involve the construction of some grand, complex-system model. It is rather

an incremental addition and extension of an existing knowledge base."

More recently, Raymond Miller writes:

> In agreement with Mackey, I do not believe that most interdisciplinary research processes are going to result in new, more comprehensive theories. … I would reformulate that [culminating] step so that it involved reevaluating all the relevant transdisciplines … to see if any of them could serve as an effective integrative strategy for the phenomena under study. (2005)

Richard Castellana (2005) applies similar concerns to undergraduate teaching when he observes that "The aim of interdisciplinary studies, at least at the undergraduate level, is not invariably to *solve* a complex problem; it is often simply to get a better *understanding* of it."

These concerns are quite understandable. Less than a decade ago, I myself argued in a review of classical essays in interdisciplinary studies that, "Taken together, the literature on interdisciplinarity is weakest when dealing with the process of integration itself. There are numerous pragmatic suggestions and a majority position, but conceptual confusion leaves the process itself unclear" (Newell, 1998). If scholars of interdisciplinarity have not been able to agree on what integration is, it's no wonder they are skeptical of claims that it can be taught, and to undergraduates no less. And for scholars dubious about my theory in general, it is to be expected that they would question the feasibility of achieving the nature and extent of integration that theory envisions.

Nonetheless, it seems to me that the capacity of undergraduates to engage in interdisciplinary integration is ultimately an empirical question. Instead of a priori debates, let's look at some data and find out. Following the observation attributed to Kenneth Boulding that "If it exists, it's possible," my response to these skeptics is to examine the 37 senior projects completed in April 2005 through the senior project workshop in the Western College Program (WCP) at Miami University and evaluate the success of these projects in achieving interdisciplinary integration. These projects are all available online* (http://www.lib.muohio.edu/theses/) so the curious or skeptical

*The availability of student theses at Miami of Ohio is in transition at the time of publication. Located through the university's digital library at the time of manuscript submission, they have now been made available through The Networked Digital Library of Theses and Dissertations. Not all theses referred to in this article are available, but may be so in the near future. We understand that the students have given permission to post the full text of their work.

reader can examine the projects to see firsthand what students can do with brief, modest, and (in their judgment) belated instruction in interdisciplinary integration. Interdisciplinary studies majors in the Western College Program take a set of interdisciplinary core courses in the humanities, social sciences, and natural sciences their first two years. In their first year they also take an interdisciplinary course each semester in fine arts or technology, for a total of 12 credits per semester of required interdisciplinary courses. Their sophomore year they also take a one-credit course that introduces them in part to literature on interdisciplinary studies and prepares them to design their own interdisciplinary concentration; second semester the courses in individual areas are replaced by a six-credit integrative seminar that draws on the humanities, social sciences, and natural sciences and applies them to a topic ("rivers" for seniors graduating in 2005). Their junior year is devoted to taking often-disciplinary courses in other divisions of the university toward their concentration and to completing the requirement of three interdisciplinary advanced seminars. In the senior year they complete their concentration courses and advanced seminars and take a two-semester 10-credit capstone—a workshop in which they write an interdisciplinary senior project. This project has a target length of 80 pages of text and must be explicitly interdisciplinary. (Projects with a major creative portion—such as directing a play, writing a collection of short stories, or conducting a set of lab experiments—have a target length of 40 pages for the analytical portion.) Interdisciplinary majors in environmental studies and environmental science take fewer interdisciplinary core courses to make room for a number of largely-disciplinary environmental or basic science courses in lieu of a self-designed concentration, but they take the senior workshop and write a comparable senior project on an environmental theme. Miami University as a whole is academically competitive, with an average ACT for entering students of 27; and while Western students represent the full range of academic skills within the University, they are disproportionately likely to be in the honors program. (They constitute about 1% of Miami undergraduates but 8% of the university honors program.) In short, students in the Western College Program are bright and take lots of interdisciplinary courses, and all of them write a lengthy interdisciplinary senior project.

While Western students repeatedly experience interdisciplinarity, they encounter little if any explicit discussion of it prior to their senior year outside a one-credit sophomore course (WCP 251). That course devotes as much time to leadership skills and preparation of a self-designed concentration as it does to interdisciplinarity, and even then its focus is conceptual, not

applied—students learn what interdisciplinary study is, not how to do it. The main reading on interdisciplinarity is Newell and Green (1982), which draws its examples from courses taught a couple decades earlier in the same program. Even in the six-credit integrative seminar (WCP 261), there is no discussion of interdisciplinary integration, much less training in techniques of integration. Thus, attention to integration is reserved for the senior project workshop (a practice that seniors have repeatedly questioned).

Prior to academic year 2003-2004, integration was discussed in the senior workshop on a largely ad hoc basis through class discussion of a past senior project and individual feedback on drafts of chapters. At the beginning of second semester 2004, a class period on integration was added, and the overheads were then posted on the Blackboard site. The next year, seniors started second semester with the same presentation on integration but shortly afterwards a just-completed chapter on decision-making in interdisciplinary studies (Newell, 2006) was posted on Blackboard in which the techniques of integration were presented as a coherent strategy for constructing common ground rather than as an undifferentiated bag of tricks. Thus, even in senior project workshop, training in interdisciplinary integration was limited mostly to those two years, with greater clarity and utility of the written explanation in 2004-2005.[1]

In the following examination of the interdisciplinary integration found in the 2005 senior projects in the Western College Program, I focus initially on examples of integration in individual projects. These examples are organized according to the integrative steps in the interdisciplinary process set out in that chapter on decision-making in interdisciplinary studies, which updates and clarifies the earlier theory of interdisciplinary studies (Newell, 2001). The goal of these detailed examples, combined with more cursory examples in the appendix drawn from the other 2005 projects, is to provide a sense of the frequency, range, and sophistication of the integrative strategies and techniques employed. I then evaluate the overall integration of each project using the interdisciplinary integration profile in the Association for Integrative Studies-sponsored assessment instrument designed by Christopher Wolfe and Carolyn Haynes (2003). That instrument currently offers the only available measure of interdisciplinary integration, though the authors have since completed a simpler version for use on shorter papers with Veronica Boix Mansilla at Harvard's Project Zero. (Although I alone scored the papers using the assessment instrument, this exploratory study demonstrates the method for analysis of undergraduate interdisciplinary outcomes.) Since Wolfe and Haynes validated the 2003 instrument using

senior projects written at Miami University, half of which were drawn from the Western College Program, a comparison of the 2005 senior projects is possible with earlier Western projects written without benefit of explicit instruction in interdisciplinary integration. Finally, I use data on grade point average, honors/non-honors, and project grade for the 2005 seniors as well as the interdisciplinary integration scale and its component categories to probe the impact of general academic skills on the integrative ability of these undergraduates.

Examples of Integration by Students

The first integrative step is "identifying conflict in insights, illuminating their source, and evaluating them." Generally speaking, if the Western seniors used disciplines to illuminate each other's assumptions, it was not directly evident in their projects. The one exception was Jason Harnish who, in his study of education for democratic citizenship, uses political liberalism and civic-republicanism to critique the other's assumptions, exposing an over-reliance on rights and duties respectively. Fully one-third of the seniors, however, were attuned to similarities and differences in disciplinary terminology and their implications for integration. The example below is drawn from Lauren Dean's interdisciplinary studies project on *The Cultural Construction Of ADHD: Conceptualizing Power in the Relationships between Adults and Children in America*. Other examples are found in the appendix.

Lauren Dean points out that attention deficit-hyperactive disorder (ADHD) affects 2 million to 4 million school-age children in America, yet a comprehensive understanding of ADHD has not been established. She finds it is defined in different (though partially overlapping) ways from the perspectives of psychology, biology, and medicine; sociology, social history, and culture studies; and education. The first group sees ADHD as a medical disorder of biological origin requiring medication, though it is unlike other disorders in that it cannot be proven through physical signs or organic tests. The second group takes a critical perspective, asserting that the causes of ADHD are cultural and societal not physiological. The third group concurs with the first that ADHD is a medical problem but often sees parents not biology as its cause. Dean looks at childhood historically to contextualize the debate and discovers that the very concept of childhood has changed greatly in the last two centuries: childhood itself is socially and culturally constructed. In the last half century, she learns, it has been

undergoing further reconstruction as women have joined the workplace and children have been placed first in kindergarten and then in pre-schools. Adult expectations of children have changed as a result, in ways that shift the definitions of "normal" and "deviant" behavior and make the behavior of ADHD children increasingly problematic. She then focuses on schools as the contemporary locus of childhood, only to find that educational theory has swung wildly over the last century. While accepting that some students have severe behavioral problems that require medication, she also concludes that many other children who do not fit the current needs of parents and the current educational ideology tend to be labeled ADHD as well. In terms of interdisciplinary integration, Dean's overall argument is based on the recognition that a number of disciplines define ADHD, "normal" and "abnormal" (or "deviant") behavior, and "childhood" differently.

The second integrative step in the interdisciplinary process is constructing common ground by bringing out latent commonalties in the conflicting insights of different disciplines. Newell (2006) identifies four techniques—redefinition, extension, organization, and transformation—that take some of the mystery out of achieving common ground. The choice of technique depends on the nature and extent of the conflict in the assumptions on which the insights are based or in the concepts through which the insights are expressed. Three possibilities exist: (a) there is no conflict, merely discipline-specific terminology or context that obscures the underlying commonalty; (b) the disciplinary concepts or assumptions are different but not opposing—merely alternatives (e.g., love vs. fear); and (c) the concepts or assumptions are diametrically opposed (e.g., rational vs. irrational). Redefinition is required whenever commonalties in concepts or assumptions are obscured by discipline-specific terminology, which is most of the time. Extension is used to address either "differences or oppositions in disciplinary concepts or assumptions by extending the meaning of an idea beyond the domain of the discipline into the domain of another discipline," and can take place across any boundary—individuals, space (regions), time (eras), races, ethnicities, classes, genders, cultures, nations, ideologies, etc. Organization moves beyond redefinition by organizing, arranging, or arraying the redefined concepts or assumptions (e.g., along a continuum, inside and outside an envelope) to bring out a relationship among them. Transformation is used where concepts or assumptions are opposed, as in dichotomies, typically by changing axiomatic assumptions into continuous variables. No matter how it is achieved, creating common ground requires both/and thinking. A third of the seniors made explicit use of one or more of the four techniques; and the reader may find implicit use (or the use of other strategies for achieving common ground) in other Western senior projects as well (available online).

Most of the techniques of integration involved some combination of redefinition and extension. The detailed example below comes from Chelsea Nagy's environmental science project on *Anthropogenic Forces Degrading Tropical Ecosystems in Latin America: A Costa Rican Study*. See Appendix for other examples.

Nagy makes the case, first, that urbanization and deforestation, driven by population growth and short-sighted land-use practices, have degraded distinctive ecologies such as coral reefs and rainforests in Costa Rica, leading to a loss of species abundance and diversity. While natural processes can produce these effects, humans have increased the frequency and intensity of the degradation. Second, she argues that human poverty and loss of the cultures of displaced indigenous populations are also exacerbated by these same forces and practices. Even agricultural development efforts such as cattle ranching and banana and coffee plantations have had these adverse human effects. Nagy probes the connection between natural and anthropogenic processes more closely by conducting an experiment on a coral reef located near the mouth of a major Costa Rican river. She finds that high levels of precipitation inland correspond to greater sediment accumulation on the reef and determines that the cause are agricultural practices that denude riparian boundaries, removing the buffer zone between cultivated land and river and thus increasing soil runoff. Turning to her integrative techniques to break down what she sees as the unwarranted and unfortunate dichotomy between economic development and environmental protection, Nagy argues that "conservation" must be redefined to include culture as well as economy and ecology, "sustainability" should be extended from the environment to human economic activity, and "needs" must be extended from humans to all species. She takes the position that those needs are interdependent, so instead of viewing them conventionally as trade-offs we should treat them as a joint maximization problem and look for "synergies in areas where the tension between them is least" (p. 107).

A few seniors used other techniques of integration. Laura Englehart advocates the transformation of the "I" of self-interested economic and political advocacy and the "We" of collective identity in social movements into a jointly maximized "I and We" for environmental advocacy. She proposes that face-to-face relationships within an environmental organization can shift members along the continuum from "I" toward "We," and then

extend the "We" for purposes of inter-organizational networking to those with overlapping but different environmental values. Les Arms, in her comparative study of mathematics and religion, transforms the dichotomies of faith and reason, and, by implication, the dichotomies of mathematics and religion. Jason Harnish generally engages in both/and thinking when he envisions citizenship education that is progressive (inquiry-based active learning), interdisciplinary (critical thinking on complex issues), essentialist (core tools, tactics, and values for critical literacy) and service-learning-oriented (connecting theory and values with practice).

The third integrative step in the interdisciplinary process is identifying linkages among disciplines. (In my earlier theory, it was identified as "searching for new information" and inappropriately linked with "gathering all current disciplinary knowledge.") At least nine seniors (or almost a quarter of the class) clearly grappled with under-explored linkages between concepts, variables, or factors from different disciplines, while several others arguably but less clearly did so as well. The detailed example below comes from Lauren Bratslavsky's interdisciplinary studies project on *Consuming Middle Class Values: Redefining the Middle Class as Facilitated by Media and Television Advertising*. For other examples, see the Appendix.

Bratslavsky argues that the wealth and income-defined boundaries of class drawn by Marxist sociology and neo-classical economics need to be reexamined in a postmodern society. Social class today is determined by the amount and type of spending instead of by source of wealth as it was prior to World War II or by the amount of wealth and income in the last half of the 20th century. The former producer-driven industrial and then service societies have been supplanted by a consumer-driven information society, changing our conception of class (especially middle class) as a result. "Facilitated largely by television, advertising, and an emphasis on consumer culture, the middle class defines itself based on consumer choices which relay notions of class status, reflect values and construct lifestyles." To understand the mechanisms producing this shift in our understanding of class, she turns to strategies of market segmentation and advertising devices. She asserts, "Market segmentation relies on the traditional notions of class, but also differentiates segments within the middle class based on lifestyles, values, and needs. Television advertising advocates various versions of middle class lifestyles by associating a product with meanings and values in order to draw a connection between the advertisement and the consumer." She identifies three adverse effects: "First, since we are constructing identities through consumption, we are encouraged to consume beyond our means in order to maintain a middle class lifestyle. Second, credit and borrowing are necessities and debt is a by-product in a consumer culture. And third, market segmentation and the commodification of values mask class inequalities." In terms of interdisciplinary integration, she probes the inadequately examined linkages between how marketers segment markets (and media display those segments in advertisements) and the conception of socioeconomic class from sociology that has been appropriated by American popular culture.

The fourth integrative step in the interdisciplinary process is constructing or modeling a more comprehensive understanding. Over half the seniors (20) took this step, though two of them utilized already-recognized frameworks instead of developing their own: Alex Allegree used the economic model of migration to organize his study of internal migration in China; and Katie Zeitler used James Joyce's own metaphor of the "nets" of Catholicism, nationalism, and Irish language to guide her study of his complex relationship to Ireland.

Let's look at Laura Englehart's interdisciplinary studies project on *Organized Environmentalism: Towards a Shift in the Political and Social Roles and Tactics of Environmental Advocacy Groups*. Englehart "analyzes the political and social positions, strategies, and tactics of environmental advocacy groups and proposes a shift in emphasis within the environmental movement" to counteract the Bush administration's anti-environmental policies. Instead of continued reliance on standard political tactics, which have been effectively counteracted, she recommends that environmentalists concentrate more on educating and politicizing within the social arena to create political opportunity structures. For a case study, she examines with approval the recent strategic changes of the League of Conservation Voters. In terms of interdisciplinary integration, she develops a model of environmental advocacy groups that balances top-down politics with bottom-up social movement organizing.

The fifth integrative step in the interdisciplinary process is testing the more comprehensive understanding by using it to solve the problem, resolve the issue, or answer the question. Forty percent of the seniors (15) completed this final step. The example below is drawn from Melissa Hamann's project on *Integrative Environmental and Public Health Policy: The Case of Leishmania in Kenya's Game Reserves*. For other examples, see the Appendix.

Hamann observes that wildlife enclosures are argued by environmentalists and politicians alike to be beneficial for surrounding indigenous populations,

yet they are a threat to public health. Biodiversity draws the tourist trade, but increased concentrations of diverse game populations also increase parasitic reservoirs and, thus, parasitic loads, jeopardizing the health of nearby human populations. She focuses on the genus leishmania endemic to Kenya. Its parasitic reservoirs are predominantly large game animals, and its vector is the sand fly that transmits leishmaniasis between host and humans. While protection from sand fly bites and treatment for the disease are technically feasible, they are sporadically used, often improperly. Hindrances to proper protection and treatment are "transportation and access to medical care, antibacterial resistance, and cost of medication." She groups accelerants to microbial traffic under the headings of changing environmental conditions, demographic changes, and deteriorating social conditions. Combining environmental and health agendas, she finds, would increase the effectiveness of routine surveillance and control of animal reservoirs, but would require a broader understanding of sustainability and its implications for individual policies. In terms of testing interdisciplinary integration through application, Hamann makes detailed recommendations on several levels (international, national, and local) for solving the problems of integrating environmental and public health policies.

Overall, with one exception all the integrative steps were taken by a third to half of the 2005 seniors in the Western College Program. The exception was the third step in the process—the identification of new linkages between disciplines, perhaps because their focus as undergraduates was on integrating existing knowledge not creating new knowledge from original data. The fact that a quarter of them *did* identify under-explored or under-utilized (and in some cases, new) linkages suggests that graduate students and certainly mature scholars might be expected to undertake this step as well.

The fears of skeptics seem unfounded that this integrative process is beyond the reach of undergraduates. After all, these seniors are academically well-prepared on average, even by the standards of Miami University as a whole; but Miami University is not an ivy league institution (though it has been dubbed a "public ivy"), the Western College Program is not a small private highly-selective liberal arts college, and the senior project is a graduation requirement for *all* Western seniors, not just for honors students.

There is a sense, however, in which I would concur with Mackey's claim that the process illustrated here expects "revolutionary science" (Kuhn, 1962) of normal "scientists." An interdisciplinary project, even one carried

out by undergraduates, *is* revolutionary in the sense that it has the potential to challenge disciplinary paradigms. But it is normal science in the sense that it follows the interdisciplinary paradigm. Indeed, my goal for interdisciplinary studies over the last quarter century has been for the profession to establish a paradigm so that interdisciplinarians could engage in "normal science." The success of these seniors indicates we now have available a candidate for that paradigm.

Evaluation of Senior Projects Using the Interdisciplinary Integration Profile

The final profile on the AIS-sponsored assessment instrument measures interdisciplinary integration. It is divided into three categories: creating common ground, new holistic understanding, and application of the new holistic understanding. The first category is, in turn, divided into five elements: presents a clear rationale for taking an interdisciplinary approach; makes assumptions from more than one discipline explicit and compares them; compares and/or contrasts disciplinary perspectives; explicitly defines problem in neutral terms that encourage contributions from more than one discipline; and creates a common vocabulary that can be applied to the object of study. The second category can be achieved through a metaphor, a model, or a new theoretical understanding, whereas the third category can be achieved through application to a new situation, application in a new way, empirical testing used to guide inquiry or solve a problem, or testing against interdisciplinary theory. Although the instrument was designed to assess the interdisciplinarity of expository writing only, I discovered that the instrument can be extended with little difficulty to apply as well to senior projects with substantial creative components.[2]

The distribution of scores on the interdisciplinary integration profile is bimodal, with 6 ones (no credit for any of the three categories), 10 twos (credit for only one category), 6 threes (credit for only two categories), 3 fours (credit for only one element of category one, plus credit for categories two and three), 1 five (credit for two elements of category one, plus credit for categories two and three), 4 sixes (credit for three elements of category one, plus credit for categories two and three), 7 sevens (credit for four or five elements in category one, plus credit for categories two and three). I interpret the bimodal distribution of scores to indicate that, roughly speaking, either students "got" how to integrate or they didn't "get it," and 40% (15 of 37) "got" the entire integrative part of the interdisciplinary process (i.e.,

their projects scored at least a 4 and thus included all three categories). This turns out to be a robust finding, in that Wolfe and Haynes also found that 40% of the 10 Western College Program projects they evaluated scored a 4 or higher.

The mean score of 3.62 (on a scale from 1 to 7) is not a revealing measure of central tendency because of the bimodal distribution (the standard deviation is 2.20). Nonetheless, when compared with the mean of 3.20 found by Christopher Wolfe and Carolyn Haynes for the earlier Western senior projects they scored, it is consistent with the fact that 2005 seniors had slightly more training in integration than did earlier seniors. Even so, given the small size of the earlier sample (n=10) and the bimodal distributions of both samples (leading to a standard deviation of 2.57 for the earlier sample), the difference is not statistically significant.

More appropriate to the bimodal distribution of profile score is a chi-square test for the difference in the proportion of Western seniors scoring high (a 4 or better) and low (less than 4). The results of that test are statistically insignificant ($\chi^2 = 0.13$), but the proportion of students achieving a high score (29.7%) is identical to the 30% found by Wolfe and Haynes.

The interdisciplinary integration profile was designed to measure how fully, not how well, a project completes the integrative steps in the interdisciplinary process. It requires yes/no, not better/worse, judgments. The project grade determined jointly by each student's advisor and by me is the best available indicator of the quality of integration of Western senior projects, though it also reflects our judgment of the quality of the first half of the interdisciplinary process, namely drawing insights from disciplines. Quality here refers to all the criteria one uses in judging any work of scholarship, including originality or depth of insight, thoroughness of research, persuasiveness of argument, and elegance or sophistication of written expression, as well as the interdisciplinarity of the project. With data available on project grades, it becomes possible to assess the usefulness of the interdisciplinary integration profile as an indicator of the quality (as distinct from the extent) of integration.

The 37 project grades[3] for the 2005 senior projects ranged from a high of A+ to a low of C-, with a mean of B+; 21 were in the A-range, 12 were in the B-range, and 4 were in the C-range. These grades are similar to grades from previous years: the average project grade over the preceding three years was a B+. The 37 projects were divided into those with a high (4, 5, 6, or 7) interdisciplinary integration profile score, encompassing

projects that met all the criteria Wolfe and Haynes propose for integration (evidence of achieving common ground, creation of a new holistic understanding, and application of that understanding), and projects with a low (1, 2, or 3) profile score (that failed to meet one or more of those three criteria).

A one-way analysis of variance (ANOVA) revealed that high profile scores accounted for 38% of the variance (R^2) in project grades: $F(1,35) = 21.43$, $p<.0001$. Mean grades (on a 1 to 12 scale) were 11.00 (straight A) for high profile scores and 8.32 (straight B) for low profile scores, with standard errors of 0.44 and 0.37 respectively. In short, profile scores are significantly correlated with project grades; indeed, profile scores "explain" almost 40% of the variation in project grades. Since project grades are the best available proxy for quality of integration, this analysis suggests that while the interdisciplinary integration profile directly measures completeness of interdisciplinary integration, it provides some indication of the quality of integration as well.

Success in Interdisciplinary Integration

Since grade point average reflects overall academic success and success in interdisciplinary integration reflects a number of academic skills, it would be reasonable to expect that GPA would be a predictor of success in interdisciplinary integration. It is not so evident, however, whether GPA should be a better predictor of the completeness or the quality of integration, i.e., profile score or project grade. When project grade is regressed against GPA, it yields the following equation: Project Grade = -1.20 + 3.09 GPA, with an R^2 of 0.347, an F-ratio of 18.6, and $p<.0001$. When profile score is regressed against GPA, it yields Profile Score = -1.63 + 1.53 GPA, with an R^2 of 0.08, an F-ratio of 3.1, and $p<.0853$. Thus, GPA is highly correlated with project grade (explaining about a third of its variance), while it is not significantly correlated with profile score. I interpret this finding to mean that students who are generally academically successful do not do all that much better than other students in completing the steps in the integrative portion of the interdisciplinary process, but they produce a much higher quality of interdisciplinary integration. This finding offers some hope for faculty teaching interdisciplinary studies to less academically successful students: those students may not produce the quality of interdisciplinary integration achieved by Western seniors, but they may be able to complete the interdisciplinary process.

This finding can be further explored by disaggregating the profile scores into the three categories of which they are comprised. When they are regressed against GPA, the following equations are estimated:

(1) Category 1 = -2.27 + 1.19 GPA, with $R^2 = 0.09$, an F-ratio of 3.6, and $p<.067$.
(2) Category 2 = -0.77 + 0.41 GPA, with $R^2 = 0.13$, an F-ratio of 5.0, and $p<.032$.
(3) Category 3 = -0.08 + 0.17 GPA, with $R^2 = 0.02$, an F-ratio of 0.6, and $p<.449$.

Only category 2 is significantly related to GPA, and then only at the .05 level. Since category 2 involves the construction of a new holistic understanding based on the common ground created in category 1, I interpret this finding as showing that academically stronger students do a slightly better job of seeing the implications of the common ground they construct, i.e., they do a somewhat better job of reasoning from premises to conclusion, but they are not particularly better at the other, more creative steps involved in interdisciplinary integration.

Conclusion

The skepticism that has been expressed about the feasibility of teaching interdisciplinary integration to undergraduates is not supported by the evidence from 2005 senior projects in the Western College Program at Miami University. These seniors are academically strong students on average who have taken numerous interdisciplinary courses but received only modest and belated training in interdisciplinary integration. Over a third of them completed almost all the integrative steps, and readers can judge for themselves the quality with which those steps were completed. There is some evidence in the data comparing current and former projects to support the repeatedly expressed contention of Western seniors that they could do a better job of integration in their senior projects if they received more and earlier training in it, or if integration were at least explicitly discussed in their interdisciplinary courses. (An interesting but tangential finding was that the interdisciplinary integration profile turns out to be a credible indicator of quality of integration as well as a measure of the completeness of integration.) Statistical analysis of project grades and scores on the interdisciplinary integration profile of the AIS-sponsored assessment instrument suggests that academically stronger students in the Western College Program are not particularly better than their classmates at completing the integrative steps in the interdisciplinary process. Where they do excel is in the quality of their integration. The one step where academically stronger students did slightly better was in creating a new holistic understanding, which mostly involves reasoning from premises to conclusions; they did no better where more creative or imaginative thinking is required. Interdisciplinary integration, as I construe it, may be revolutionary science in the sense that it has the potential to challenge disciplinary paradigms, but it doesn't require a Newton, Darwin, or Marx to undertake it. Nor does it need a mature scholar. Undergraduates can be taught to engage in interdisciplinary integration.

Notes

[1] This lack of explicit attention to interdisciplinarity in general and integration in particular is unfortunately common in long-standing interdisciplinary programs. See Newell et al. (2003).
[2] I discovered a shortcut in scoring the projects that speeds up considerably the use of the instrument. Since the projects are all available online in PDF format, I could enter "interdisciplinar," "assum," and "perspective" in the search option to find quickly where a project might meet the requirements for the first three elements in the first category. When I read the projects to grade them, I took notes on their use of the integrative steps, so it only took me one full additional day to score 37 projects using the profile.
[3] For creative projects, the grade used was only for the analytical portion.

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Appendix

Integration in 2005 Senior Projects

First Integrative Step

Additional examples of the first integrative step in the interdisciplinary process—"identifying conflict in insights, illuminating their source, and evaluating them": ***Chelsea Nagy***, in her study of the human degradation of tropical ecosystems in Costa Rica, points out that "wealth" is defined in different and non-overlapping ways by economics (monetarily) and environmental studies (biodiversity and ecosystem health). In her project on memory and emotion, on the other hand, ***Diane Jones*** concludes that the more than 30 terms used by researchers from cognitive psychology and neurobiology to describe basic emotions can be reduced to four: fear, anger, sadness, and happiness. ***Becky Singson***, in her study of end-user research for Web design, decides that different terms for end-user (e.g., user, research user group, customer, audience, target audience) have only slight variations in meaning as they come out of the disciplines of marketing, psychology (computer-human interaction specialists), and computer science (programmers).

Second Integrative Step

Additional examples of the second integrative step—constructing common ground by bringing out latent commonalties in the conflicting insights of different disciplines: ***Lia Silver***, in her study of the appropriation of social identity in fiction, believes that "appropriation of identity" must be redefined to include fiction writing as well as acting and filmmaking. In his study of Buddhism and the Beat generation, ***Nathaniel Gay*** asserts that, when the Beats introduced Buddhism into the United States in the 1950s, they redefined it in a way that incorporated American individualism while challenging American materialism. ***Melissa Hamann***, in her study of leishmaniasis in Kenyan wildlife reserves, discovers that "reserves" and "reservoirs" need a common term, since wildlife reserves have indeed become parasitic reservoirs in Kenya if not worldwide (with severe health consequences for the local human population). She extends the concept of "sustainability" even further than Nagy does to include the political system. ***Sophia Turczynewycz***, in her study of inclusive environmental education, argues that environmental and inclusive education share a common

"respect for others" where "others" is defined more narrowly by the latter as "differently-abled people" and more broadly (i.e., extended) as "other species" by the former. In *Bilingualism as Prejudice Prevention*, ***Audrey MacWood*** extends the concept of multiculturalism to include native-language education by including "language" in "culture." ***Bethany Weber***, in her study of community art as a tool for community development, extends "community development" from an economic, social, and political concept to one that includes culture as well. In her study of customer service, ***Karen Schoenfeld*** extends the need for repair from the broken copy machine to the customers unable to make copies, and extends the concept of empowerment from employees to customers through co-production such as self-service checkout, gasoline pumping, and salad bars. In his discussion of fiction writing through reverse storyboarding, ***Austin Kleon*** extends the concept of world building from fantasy to fiction in general, examining the limitations of its contributions (i.e., to plot but not to narrative) as well as its strengths (for authors who think visually and well as verbally). In her study of micro-finance in Latin America, ***Sarah Arnason*** extends the scope of neo-liberalism to include impoverished entrepreneurs normally failed by the market.

Third Integrative Step

Additional examples of the third integrative step in the interdisciplinary process—identifying linkages among disciplines: ***Diane Jones*** devotes much of her project to identifying the (rather messy) interactions between memory and emotions, with psychology providing cognitive information on the mind and mental processes, and biology providing neurological information on the brain and physiological processes. She does this almost entirely by reviewing published literature from each discipline that is often overlooked by the other discipline, and by evaluating where (much) more research needs to be done, though she herself conducts one small study. ***Katie Gibson*** likewise devotes most of her project to studying the unexamined impacts of U.S. foreign policy on Latin American culture. Instead of reviewing published literature, she focuses on a single case study—an original examination of the impact on Gabriel Garcia Marquez's *One Hundred Years of Solitude* of U.S. economic and political policy towards Columbia. ***Nathaniel Gay*** focuses his project on the Beats as the historical link between Asian and American Buddhism, examining the linkages through Kerouac's *Dharma Bums* as well as his journals and the texts on Buddhism they reveal that he read. The thesis of ***Brad Shumaker***'s project on modernization in Oceania is that indigenous identity has been shaped by the interactions of history (seen differently by explorers, indigenous people, and colonial historians), culture, media portrayal, and politics. He identifies feedback effects from colonial attitudes and representation on the psychology of indigenous people. The thesis of ***Bethany Weber***'s project is that community art links community organizing and public art. She advocates a service learning approach to community art that links community art and academic learning through the joint construction of murals by students and community members, and she theorizes about the nature of their linkages. Similarly, ***Abby King*** in her study of community art asserts that the intersections of art and organizing are mutually reinforcing or synergistic, such that each can productively influence how the other is done. ***Lia Silver*** focuses her study of appropriation in fiction writing on two case studies, race and gender, theorizing that the impact of race (for example) on appropriation is quite different for a minority writer appropriating the identity of a majority character, and for a majority writer with a minority character. She points out that she chose two case studies instead of one precisely so that she could examine their interactions effects, though again the effects are hypothesized. ***Chelsea Nagy*** examines the linkages already identified in the literature between poverty and environmental degradation such as deforestation compounded by poorly constructed timber leasing agreements and poorly enforced property rights, though she makes a contribution to that literature as well through her study of the effects of runoff due to denuded riparian boundaries on coral reefs near a river's mouth.

Fourth Integrative Step

Additional examples of the fourth integrative step in the interdisciplinary process—constructing or modeling a more comprehensive understanding: From the strengths of the existing models he examines, ***Jason Harnish*** identifies five key requirements for education for democratic citizenship; in achieving this understanding, he balances out ideological as well as disciplinary perspectives. In a discussion of his autobiographical short story, ***Dustin Daugherty*** brings insights into masculine identity from men's studies, creative writing from satire, and identity formation from constructivism together in a

fiction-writing tool he calls "creative identity deconstruction." ***Sophia Turczynewycz*** explains how the "respect for others" connecting inclusive and environmental education can form the basis for a sense of connectedness and then community through embracing (and eventually valuing) difference. In her study of the covers of Newbery Award-winning books, ***Kelly Markle*** shows how the inputs of artist, editor, and marketer combine to produce book covers that are more concerned with selling books than with reflecting their contents. ***Les Arms*** constructs a general theory of the creation of systems such as mathematics and religion, namely that they are created to "bring people a sense of certainty about the world"; yet they require faith as well as reason to provide that certainty, and she introduces a parallel-lines metaphor for the relation between mathematics and religion. ***Abby Workman***, in her discussion of her theatrically-staged production of Tom Stoppard's radio-drama *Artist Descending a Staircase*, identifies the issues involved in integrating elements from both media into a coherent production. In discussing her production of *West Side Story*, ***Maggie Perrino*** sets out a process for expanding character-building into "culturally educational theatre" for actors through a sequence of reading and research assignments, one-on-one discussions with actors, and then discussions among actors. ***Lauren Dean*** sees ADHD as the product of different motivations of parents, teachers, and now psychiatrists and the genetically and socially-induced behavior of children with inconvenient learning styles which reflects a misunderstanding of childhood (that has unfortunate consequences for children). ***Lauren Bratslavsky*** finds that the recent linkage of market segmentation with socioeconomic class in the United States has shifted the definition of class from variables such as income, occupation, education, and residence to a media-driven image linking class with expenditure (much as an earlier shift in definition had linked class with income instead of source of wealth). ***Austin Kleon*** integrates writing notebook and sketchbook through a sequence from images, cluster maps, and panels of scenes in random order leading to the first draft of a short story for which the plot is discovered through the physical act of writing. (He also integrates his project itself by alternating its analytical and creative portions in a way that plays each off against the other, with the intention of integrating them into a coherent whole.) ***Chelsea Nagy*** develops a cancer metaphor for interaction of poverty and environmental degradation. Based on her examination of appropriation of identity in the contexts of racial and gender differences between

fiction writers and their characters, ***Lia Silver*** identifies three criteria for ethical implicature (which is the ultimate level of empathy): (a) awareness of one's own ethnocentric feelings; (b) extended exposure to the social identity outside one's own; and (c) hyper-connective thinking through emotion. In his study of the Smart Growth potential of brown field redevelopment, ***Dave Smith*** views brown fields as an economic, environmental, and social-equity problem, so that their redevelopment simultaneously solves several problems normally seen as separate. ***Melissa Hamann*** shows how wildlife reserves in Kenya can (indeed, must) be understood as an integrated issue that involves public health as well as environmental and economic concerns. In her study of the influence of family on eating disorders, ***Libby Carey*** offers the metaphor of eating disorders as an infectious disease: some families provide an environment that nurtures the disease. ***John Neborak*** develops a cognitive psychology-based understanding of visual-verbal blending through a study of comics and film writing that informs his own science fiction script. ***Becky Singson*** integrates research methods from different disciplines into a systemic approach to end-user research for Web site development. ***Jason McDonald*** makes the case that multiple speciation techniques (chemical extraction, X-ray diffraction, and scanning electronic microscopy) are needed to assess the different aspects of the complex interactions between an element and its environment. It is only through a combination responsive to the distinctive characteristics of element and environment, he says, that the complex whole can be assessed. Seen more broadly as part of environmental policy, issues of quality control, politics, and costs (certified reference materials, expensive equipment, and skilled technicians' time) will also enter into the forthcoming Environmental Protection Agency decision about using chemical speciation at Superfund sites.

Fifth Integrative Step

Additional examples of the fifth step in the interdisciplinary process—testing the more comprehensive understanding by using it to solve the problem, resolve the issue, or answer the question: ***Sophia Turczynewycz*** examines specific pedagogical opportunities at the intersection of inclusive and environmental education, noting that some (such as differentiated instruction) have the potential for benefiting mainstream, even gifted, students as well as differently-abled students, and concluding that the extent of training of teachers in these pedagogies

can make the difference between a program that benefits everyone (all students and all species) and one that lets down even the disadvantaged. ***Kelly Markle*** applies her interpretive model of the covers of specific Newbery-award winning books and concludes that authors as well as artists, marketers, and editors need to be involved in their design if these books are to be read or even opened by kids. In her production ***Abby Workman*** solves the adaptation problem (of a radio-drama written to be unstageable in a theatre) by inventing techniques to mimic or suggest the radio medium within the theatre medium: sound effects were done live in the center back of the stage, and lighting and costumes "signed" the audience's imagination characteristic of radio. The biggest challenge she overcomes is a joke relying on sound without sight; i.e., an actor apparently riding a horse who, the audience eventually discovers, is merely clicking coconut shells together. ***Lauren Bratslavsky*** applies her model of redefined class to an analysis of contemporary media and culture, and concludes that the decoupling of class and income has led to the dramatic increase in consumer debt and thus to more frequent advertisements for credit cards, debt consolidation, and lawyers specializing in bankruptcy. She also offers a clay metaphor for how media shape but do not create consumer needs. ***Laurel Englehart*** applies her top-down and bottom-up understanding of environmental advocacy to the League of Conservation Voters and largely endorses the organizational and tactical changes it has made in recent years, while advocating even more networking with other environmental organizations. ***Jason Harnish*** points to an interdisciplinary-democracy citizenship model that conforms to his five requirements for education for democratic citizenship, identifying the elements drawn from each of the current competing models. ***Austin Kleon*** and ***Dustin Daugherty*** each writes a new short story utilizing the writing process he developed based on earlier short stories, while ***John Neborak*** writes a script making direct use of the techniques he identifies for visual-verbal blending, modifying them to fit his comics medium. ***Sarah Arnason*** applies her model of microfinance to current nongovernmental organization (NGO) practices in Latin America, and advocates the bifurcation of microfinance institutions into programs providing commercial loans to successful earlier clients who now require larger loans and represent less of a risk, alongside programs faithful to the original vision of serving the poorest entrepreneurs who represent too great a risk for commercial loans. ***Chelsea Nagy*** explores three solutions to economic,

environmental, and cultural sustainability—agro-forestry, eco-tourism, and organic farming—arguing that the choice of policy must be tailored to the distinctive characteristics of each locale through local as well as national decision-making. Appropriate tools include Geographical Information Systems (expanded to include socioeconomic and cultural as well as scientific data) and education (which affects behavior such as lower birthrates, awareness of larger implications of local practices, decision-making skills, and values). ***Dave Smith*** examines in detail a number of federal policies designed to reduce the risks associated with brown field redevelopment. ***Becky Singson*** advocates the construction of personas as a low-cost solution to the problem of integrating the end-user research in Web design that is compiled using the methods of different disciplines. ***Jason McDonald*** applies his integrated speciation model to the characterization of lead contamination at a cleanup site in Florida, determining that the predominant forms are organic and Fe/Mn oxide phases while the minor mineral constituents are anglesite (lead sulfate) and rulite.