Evaluating an Interdisciplinary Undergraduate Training Program in Health Promotion Research

Shalini Misra, MS, Richard H. Harvey, PhD, Daniel Stokols, PhD, Kathleen H. Pine, Juliana Fuqua, PhD, Said M. Shokair, John M. Whiteley, PhD

Background: The University of California at Irvine Interdisciplinary Summer Undergraduate Research Experience (ID-SURE) program had three objectives: (1) designing an interdisciplinary health promotion training curriculum for undergraduate research fellows; (2) developing measures for evaluating and assessing program-related educational processes and products; and (3) comparing these educational process and product measures between groups of students who did or did not receive the training.

Methods: A total of 101 students participated in the ID-SURE program during 2005, 2006, and 2007. A longitudinal research design was employed whereby students' interdisciplinary attitudes and behaviors were assessed at the beginning and end of the training program. The interdisciplinary and intellectual qualities of students' academic and research products were assessed at the conclusion of the training activities. In addition, ID-SURE participants' interdisciplinary attitudes, behaviors, and research products were compared to those of 70 participants in another fellowship program that did not have an interdisciplinary training component.

Results: Exposing undergraduate research fellows to the interdisciplinary curriculum led to increased participation in, and positive attitudes about, interdisciplinary classroom and laboratory activities. Products, such as the integrative and interdisciplinary quality of student research projects, showed no differences when compared to those of undergraduates who were not exposed to the interdisciplinary curriculum. However, undergraduates exposed to the training engaged in more interdisciplinary behaviors at the end of the program than students who were not trained in interdisciplinary research techniques.

Conclusions: The findings from this study offer evidence for the efficacy of the ID-SURE program for training undergraduate students in transdisciplinary concepts, methods, and skills that are needed for effective scientific collaboration. Additionally, this study makes two important contributions to the development and evaluation of interdisciplinary health research training programs: (1) It presents and evaluates a novel curriculum for training undergraduate students in interdisciplinary theories, concepts, and methods of health promotion that can be replicated in other settings and contexts; (2) It provides and tests the reliability of new measures for evaluating interdisciplinary collaborative processes and develops objective criteria for rating the integrative and intellectual quality of students' research products.

(Am J Prev Med 2009;36(4):358–365)

Introduction

There has been growing support for cross-disciplinary approaches to research and training during the past 2 decades.[1–4] For example, the NIH Roadmap Initiative (www.nihroadmap.nih.gov) supports large-scale interdisciplinary projects with the broad goal of improving public health and advancing knowledge of biology and biological systems. Examples of NIH initiatives that emphasize interdisciplinary research and training strategies include the National Cancer Institute's Transdisciplinary Tobacco Use Research Centers (www.dccps.nci.nih.gov), Transdisciplinary Research on Energetics

From the School of Social Ecology (Misra, Stokols, Pine, Whiteley), the Undergraduate Research Opportunities Program (Shokair), University of California Irvine, Irvine; Department of Health Education, San Francisco State University (Harvey), San Francisco; and the Department of Psychology and Sociology, California State Polytechnic University (Fuqua), Pomona, California

Address correspondence and reprint requests to: Shalini Misra, MS, Department of Planning, Policy, and Design, UC Irvine, 202, Social Ecology I, Irvine CA 92697. E-mail: shalinim@uci.edu.

0749-3797/09/$–see front matter
doi:10.1016/j.amepre.2008.11.014

Center (www.compass.fhcrc.org), Centers for Excellence in Cancer Communications and Research (www.cancercontrol.cancer.gov), Centers for Population Health and Health Disparities (www.cancercontrol.gov), and the National Center for Research Resources' Clinical Translational Science Centers (www.ncrr.nih.gov).

Several programs have been designed to foster interdisciplinary thinking at the undergraduate level. For example, the Institute for Health Promotion and Disease Prevention Research at the University of Southern California provides mentorship for undergraduates in health promotion studies, and the University of California Los Angeles's Freshman Cluster Program requires students to take year-long, collaboratively taught courses on interdisciplinary topics (e.g., biotechnology and society, global environment). Other such programs exist at the Universities of Michigan, Oregon, Texas at Austin, and Wisconsin.

Whereas existing programs provide exposure to either interdisciplinary courses or research activities, the University of California Irvine (UC Irvine) Interdisciplinary Summer Undergraduate Research Experience (ID-SURE) program (www.urop.uci.edu) combines interdisciplinary coursework with an intensive summer research fellowship experience. One of the very few interdisciplinary training programs for undergraduates, ID-SURE aims to foster a new generation of scientists and practitioners equipped with the integrative conceptual and methodologic skills to solve the health challenges of the future. Given the interdisciplinary scope of the public health field, and of health promotion and disease prevention more specifically, the ID-SURE program was created to provide undergraduates with collaborative opportunities, exposure to disciplines other than their own, mentorship from faculty representing diverse fields, and training in interdisciplinary theories and methods.

Evaluating the educational outcomes of the ID-SURE program was one of the main objectives of the present study. Relatively few methods or metrics have been created to evaluate the processes or products resulting from undergraduate interdisciplinary training programs.[2,3,5,6] Recognizing these knowledge gaps, this study had three major objectives: (1) designing an interdisciplinary health promotion training curriculum for undergraduate research fellows; (2) developing measures for evaluating and assessing program-related educational processes and products; and (3) comparing these educational process and product measures between groups of students who did or did not receive the training. These comparison programs were the UC Irvine Integrated Micro/Nano Summer Undergraduate Research Experience (IM-SURE) program and the Summer Undergraduate Research Fellowship for Information Technology (SURF-IT) program.

Developing an Interdisciplinary Training Program for Advanced Undergraduates

Rosenfield[7] distinguishes between various forms of cross-disciplinary science in which multidisciplinary research is characterized by more independence among scientists as compared to interdisciplinary research, which entails greater collaboration among scientists. According to Rosenfield, transdisciplinarity is the most robust, integrated form of cross-disciplinary research whereby scholars from multiple fields work together to create new conceptual models and methodologies that integrate and transcend their respective disciplines. Mitrany and Stokols[8] suggest that exposing advanced undergraduates to interdisciplinary research perspectives can nurture a transdisciplinary orientation in later research. However, Lattuca[2] points out that there is little evidence that interdisciplinary courses expand graduate students' or doctoral researchers' capacity to integrate concepts, theories, and methods from different fields.

Whereas there have been no studies examining interdisciplinary research perspectives in undergraduates, some studies[7,9–11] have identified several factors that facilitate the gradual development of inter- and trans-disciplinary orientations among scientists trained initially in unidisciplinary fields. For example, Nash and colleagues,[4] after examining multi- or inter-disciplinary graduate training programs, proposed curricular models for steadily strengthening transdisciplinary education, along with tools for evaluating those programs.[3,4] According to Nash et al.,[4] interdisciplinary training programs should incorporate these key components: (1) teaching interdisciplinary courses using a team (multi-mentor model) or, using a single instructor trained in interdisciplinary concepts and methods (single-mentor model); (2) instituting forums for frequently exchanging scholarly ideas between faculty and students; and (3) promoting an institutional climate of openness, respect, and trust that encourages examining new ideas and experimenting with novel research methodologies.

The ID-SURE training program design was guided by the three components proposed by Nash and colleagues.[4] Specifically, the components are: (1) teaching by a team of faculty from a major research university; (2) a regular "journal club" format providing a time and place for idea exchange; and (3) administration by a School of Social Ecology that encourages faculty and students to integrate disciplinary perspectives in their research, as well as an Undergraduate Research Opportunities Program noted for encouraging undergraduate research. The program administrators awarded fellowships based on the quality of each student's research proposal, recommendations by faculty mentors, and the student's overall grade point average (GPA).

Undergraduates participated in a 10-week spring-quarter course entitled "The Social Ecology of Health Promotion and Disease Prevention" with the goal of applying new insights and methodologies toward understanding and reducing contemporary public health problems. The curriculum included: (1) introducing students to the concepts, theories, and methods of interdisciplinary research; (2) providing opportunities for applying interdisciplinary theoretic models and techniques for analyzing community health problems; and (3) affording students the experience of working with interdisciplinary research teams, thereby facilitating their learning of collaborative behaviors.

Curricular and Team Training Activities

The spring-quarter course included ten weekly 3-hour classes consisting of didactic lectures presented by faculty members from departments such as psychology; anthropology; medicine; psychiatry; cell and developmental biology; planning, policy, and design; and environmental health sciences, all of which are engaged broadly in interdisciplinary research related to health promotion and disease prevention. The course also incorporated intensive, 2–3-hour team training exercises aimed at helping students develop creative ideas, effective leadership styles, and communication strategies. Teams consisted of five members representing at least four different disciplinary backgrounds who worked together over the course of the quarter to prepare and present health-related research projects.

Students were trained to incorporate the inter/transdisciplinary and social ecologic concepts they had learned about during the weekly lectures. Their ideas were tracked using response sheets that asked for their reactions to the weekly lectures and readings. The questions on the response sheets probed students' understanding of inter/transdisciplinary principles, social ecologic concepts, and tenets of health promotion and disease prevention presented in each week's lecture and assigned readings. Students also took two quizzes consisting of short-answer questions covering the weekly readings and lectures.

Finally, students individually wrote a ten-page "idea paper" on a topic related to health promotion, disease prevention, or both. For their paper, students were encouraged to integrate class material about developing new theories, concepts, or ideas, extending existing ones, or proposing new methodologies for understanding and resolving pressing societal health concerns such as the obesity and diabetes epidemics, tobacco control, cancer, heart disease, environmental pollution, and food insecurity.

During the summer portion of the training program, ID-SURE fellows participated in six weekly journal club meetings. Similar to traditional journal club meetings in which individuals meet to analyze and evaluate scientific articles, fellows were assigned readings before each session and were expected to be able to discuss them with peers and faculty. Faculty who were engaged in interdisciplinary research were invited to share their scholarly and personal experiences with the students, and students had a chance to ask questions about the readings or inter/transdisciplinary concepts in general.

In addition to these curricular experiences, ID-SURE fellows completed 320 hours of laboratory or field research activities related to health promotion and disease prevention supervised by their faculty mentors over a 10-week period during the summer. Fellows were required to present the results of their summer research projects at the end of the internship period.

Key Hypotheses and Logic Model

The current study evaluated the major components of the ID-SURE training program, such as the final research project, working in a research laboratory with interdisciplinary mentors, attending classes, and reacting to selected readings and lectures. The logic model, shown in Figure 1, highlights the major program components and their expected outcomes. It was hypothesized that the curriculum would result in changing interdisciplinary behaviors and perspectives, which in turn would increase the interdisciplinary quality of products including the students' idea papers and final summer projects.[a]

The following five hypotheses were made:

1. The training components would increase the prevalence of transdisciplinary behaviors such as reading articles from disciplines other than one's own and valuing working with colleagues outside one's discipline.
2. The curriculum would promote the development of interdisciplinary perspectives exemplified by shifts from unidisciplinary to inter- or trans-disciplinary research orientations over time.
3. The ID-SURE curriculum (e.g., lectures by faculty from diverse departments, research collaboration with a faculty mentor, and journal club sessions) would be associated with greater integrative and intellectual quality of students' research products, such as their final projects. This relationship was

[a]Students' papers were graded on the extent to which they demonstrated an integration of class material about theories, concepts, or ideas that bridged several disciplines and levels of analysis, and novel methodologies for understanding and resolving pressing societal health concerns. Students were specifically instructed to be interdisciplinary in their idea papers, but no evaluation was made of whether they changed their transdisciplinary orientations on the basis of this course requirement. However, students conducted their summer research projects under the guidance of their fellowship faculty mentors and were not asked to be interdisciplinary and were not graded on their final projects by the spring-quarter course instructors. Thus, only students' final (summer) research project reports were used as a product evaluation measure.

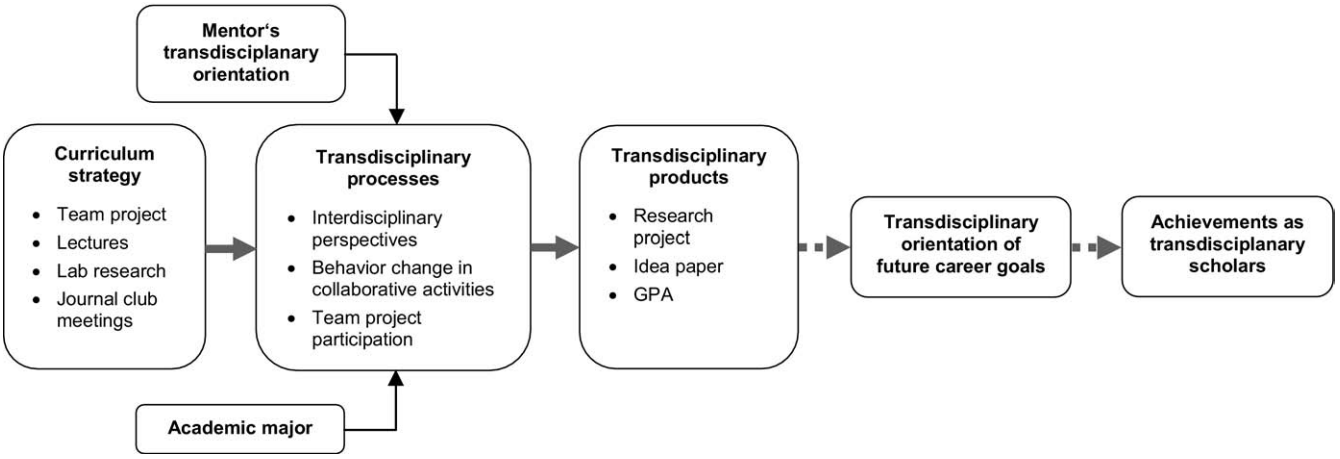

Figure 1. Logic model highlighting key program components and outcomes

expected to be moderated by the faculty mentor's research orientation (e.g., unidisciplinary versus transdisciplinary). That is, greater interdisciplinarity among mentors would lead to greater interdisciplinarity among fellows.

4. The ID-SURE fellows would display greater shifts toward transdisciplinary activities and values and achieve higher levels of integrative quality in their final projects than students in the IM-SURE or SURF-IT fellowship programs.
5. The ID-SURE training would lead students to develop a transdisciplinary orientation in terms of their attitudes toward using multiple disciplinary approaches and methods, their open-mindedness toward diverse research perspectives, and the extent to which they enjoy collaborative work.[b]

Methods

Participants

A total of 103 participants enrolled in the ID-SURE fellowship program during 2005, 2006, and 2007. Two fellows withdrew from the program, yielding a final total of 101 participants. There were no significant demographic differences between the students in the IM-SURE and the SURF-IT groups, so these groups were combined for all statistical comparisons for a total of 70 students in the comparison group. Likewise, there were no significant differences between the ID-SURE and the IM-SURE/SURF-IT samples with respect to age, gender, or ethnicity. The two comparison groups were similar also because they attended the same university and participated in research fellowship programs for advanced undergraduates with the same award criteria used in the ID-SURE fellowship program, except that the comparison programs did not include a curricular component designed to train students in interdisciplinary research strategies. Table 1 provides a summary of the demographic characteristics of the ID-SURE fellows.

There were 23 research mentors in the program, representing the biological sciences (e.g., biomedical engineering, neurobiology, and pharmacology) and social sciences (e.g., anthropology, psychology, and sociology). Several of these individuals mentored multiple ID-SURE fellows. Each mentor was surveyed to assess their research orientations (e.g., ranging from uni- to trans-disciplinary perspectives) as conceptualized by Rosenfield.[7]

Process and Product Measures

Mitrany and Stokols[8] suggest two methodologic strategies for evaluating the transdisciplinary qualities and outcomes of doctoral training programs and dissertations. Process measures include self-reports of the influence of coursework, research mentorship, and scholarly exchanges along with one's intellectual values, attitudes, and behaviors. Product measures include external, objective appraisals of the transdisciplinary qualities of published papers, theses, and dissertations. They developed composite scales for assessing the transdisciplinary scope of doctoral dissertations that can be

Table 1. Demographic characteristics of ID-SURE fellows (n=101)

	n (%)*
Age (M [SD])	21.02 (3.5)
Gender (Male)	51.5
Race	
Caucasian	24 (23.8)
Asian	27 (26.7)
Pacific Islander	5 (5)
Latino/Hispanic	7 (6.9)
African American	1 (1)
Middle-Eastern	13 (12.9)
Other/missing	22 (21.8)
Total	101

*Unless otherwise noted
ID-SURE, University of California at Irvine Interdisciplinary Summer Undergraduate Research Experience

[b]Although no direct assessment was made of students' scholarly achievements following their undergraduate education, qualitative data were collected about students' future career plans as an indirect measure of their future interdisciplinary orientation. Direct measures of students' longer-term academic and career achievements could be assessed through a follow-up study of ID-SURE graduates as they progress through later stages of their careers.

applied to a wide range of training and research programs. The present study adapted the Mitrany and Stokols[8] measures by developing criteria to assess the intellectual processes and products of the ID-SURE training program.

Process evaluation measures. Evaluating the process measures of transdisciplinary behaviors and attitudes required establishing the reliability of the measures by computing the inter-rater reliability of written product rating scales (e.g., Cohen's kappa statistic)[12] and the internal reliability of survey scales (e.g., Cronbach's alpha statistic).[13] The relevant alpha or kappa statistics appear in parentheses in the descriptions associated with the following six measures:

1. The behavior change collaborative activities index (BCCAI) assessed students' self-reported collaborative activities.[10,14,15] This 8-item scale (α=0.843) had students acknowledge any transdisciplinary collaborative behaviors such as participating in groups with researchers in other fields with the intent to integrate ideas, designing a new collaborative study, and taking classes outside one's major.
2. The interdisciplinary perspectives index (IPI) measured transdisciplinary orientations and values. This 6-item scale (α=0.930) evaluated students' attitudes about using multiple disciplinary approaches and methods (i.e., the extent to which they value interdisciplinary work, are optimistic about the scientific outcome of such work, have tolerance of and open-mindedness toward research perspectives other than their own, use multiple research methods from many disciplines, believe that a high degree of goodwill exists among their research collaborators, and believe that the benefits of interdisciplinary research outweigh the inconveniences).
3. The team project participation scale (TPPS) gauged students' evaluations of the team project they completed. This 5-item scale (α=0.859) assessed the degree to which ID-SURE fellows found their collaborative teamwork useful, enjoyable, easy to coordinate, effective in introducing them to principles of transdisciplinary collaboration, socially cohesive, promotive of their intention to stay in touch with their teammates in the future, useful for encouraging intellectual development, and "even" or "uneven" regarding the respective contributions of team members.
4. The laboratory impressions scale (LIS) assessed the collaborative qualities of students' summer research settings. This 5-item scale (α=0.859) gauged the fellows' intellectual and affective experiences in their laboratory settings. A 7-point semantic differential scale[16] was administered with the following pairs of adjectives: frustrated/satisfied, intellectually isolated/intellectually integrated, pessimistic/optimistic, alienated/integrated, and progress hindered/progress advanced.
5. The social climate scale (SCS) evaluated fellows' impressions of the social climate in their labs. This 5-item scale (α=0.832) gauged social aspects of the lab experience. A 7-point semantic differential scale[16] was administered with the following pairs of adjectives: encouraging/discouraging, competitive/cooperative, stimulating/unstimulating, cold/warm, and socially fragmented/socially cohesive.
6. The interdisciplinary scientific appreciation index (IDSAI) measured the degree to which fellows valued and enjoyed inter/transdisciplinary collaboration. This 4-item scale (α=0.836) assessed the degree to which fellows valued and appreciated inter/transdisciplinary collaboration, as well as the extent to which they found the application of transdisciplinary collaborative techniques useful and enjoyable. The composite index combined items from the measures above, as follows: valued interdisciplinary work, appreciated interdisciplinary research collaboration, and found it useful and enjoyable to work collaboratively as a team.

Product evaluation measures. For reliably assessing the intellectual quality and integration of products (summer research projects), the present study adapted the measures used by Mitrany and Stokols[8] to assess "the extent to which there is successful or effective integration of concepts, methods, and findings between fields" and "the extent to which the paper/project reflects a high level of intellectual quality in its conceptualization and/or methods." Using a 10-point scale, judges rated two performance outcome measures: final project integration and final project quality.

As noted by Rosenfield,[7] researchers at any level (e.g., undergraduate or doctoral) or developmental stage (e.g., multi- or trans-disciplinary) can achieve varying levels of transdisciplinary integration in their scholarly products. In this study, a research project or paper that rated very high (9 or 10) on the integration scale bridged ideas from several disciplines through the development of novel conceptual frameworks or theories that go beyond the theoretic and methodologic boundaries of individual fields. In addition to integrative quality, judges evaluated fellows' research products for their intellectual quality (e.g., the extent to which they demonstrated creative conceptualization of the research topic, methods, and findings; presented their findings clearly and cogently; and showed potential for making a significant contribution to health promotion and disease prevention). Raters were selected for their ability to judge the products in the fields of health promotion, nanotechnology, and information technology. There was a high degree of inter-rater reliability for all of the comparisons, with Cohen's kappa statistic for the four product measures ranging between .961 and .986.

Qualitative interviews. Focus group and individualized interviews were conducted with 19 ID-SURE fellows from the 2006 cohort at the conclusion of their 10-week summer research internship. The purpose of the interviews was to gain a better understanding of the influences of the ID-SURE training and research experience on the fellows' academic, professional, and personal lives. To gauge the possible longer-term effects of transdisciplinary training, fellows were asked about their future goals and whether they expected to incorporate what they learned in the ID-SURE program into their future career plans.

Procedures

For all the fellows, the BCCAI and the IPI were administered at the beginning (Time 1: early spring), middle (Time 2: early summer), and end of the program (Time 3: late summer). The TPPS was administered at Time 2, before the summer journal club and after the students had worked on their team projects during the spring quarter. The LIS and SCS were administered at Time 3, the end of the program. Mentors

Table 2. Bivariate correlations of key study measures

Measure	BCCAI	IPI	TPPS	LIS	SCS	IDSAI
BCCAI	1	−0.048	0.585**	0.008	0.324**	0.384**
IPI	−0.048	1	0.218*	0.007	0.312**	0.493**
TPPS	0.585**	0.218*	1	0.306*	0.404**	0.645**
LIS	0.008	0.007	0.306*	1	0.690**	0.071
SCS	0.324**	0.312**	0.404**	0.690**	1	0.200*
IDSAI	0.384**	0.493**	0.645**	0.071	0.200*	1

*$p<0.05$; **$p<0.01$

BCCAI, behavior change collaborative activities index; IDSAI, interdisciplinary scientific appreciation index; IPI, interdisciplinary perspectives index; LIS, laboratory impressions scale; SCS, social climate scale; TPPS, team project participation scale

completed the BCCAI and the IPI at Time 2. Rating of team projects occurred at the end of the program for each cohort. Interviews, however, were conducted only during summer 2006 using Cohort 2 of the ID-SURE program.

Analysis Plan

Prior to conducting the main data analyses in 2007, statistical assumptions of power, homogeneity of variance, and homogeneity of regression were assessed.[c] No significant departures from these statistical assumptions were observed. Bivariate correlations, repeated measures ANOVA, and linear regression analysis were planned for this study.

Results

One of the study goals included measuring interdisciplinary processes and products resulting from the interdisciplinary training program. Correlations between the process measures (described more fully in the Methods section) appear in Table 2. Note the significant positive correlations between the final project, as measured by the TPPS, and two other measures: the IDSAI ($r=0.645$, $p<0.001$) and the BCCAI ($r=0.585$, $p<0.001$).

The following results correspond to the hypotheses stated above. The first and second hypotheses considered how the program curriculum influenced behaviors and attitudes in the fellows. Hypothesis 1 was that the training increased the prevalence of transdisciplinary behaviors, as indicated by the BCCAI. A repeated measures ANOVA showed a highly significant main effect for time, $F(1,61)=27.15$, $p<0.001$ in the expected direction. Hypothesis 2 was that the training increased the prevalence of transdisciplinary perspectives, as indicated by the IPI. A repeated measures ANOVA showed a highly significant main effect for time, $F(1,82)=5.26$, $p<0.05$, also in the expected direction.

In addition to changes in behaviors and attitudes, Hypothesis 3 was that the ID-SURE curriculum, moderated by the faculty mentor's research orientation, was associated with greater integrative quality of their products, such as their final summer research projects. Changes in attitudes due to the ID-SURE curriculum, as measured by the IPI, showed the program's influence on final projects. For example, using the IPI to predict final project quality, the regression model fit was modest but significant, adjusted $R^2=0.038$, $F(1,81)=4.16$, $p<0.05$.

Additionally, the IPI as well as the BCCAI were used to measure the influence of mentors on fellow interdisciplinary behaviors and perspectives. Changes in attitude due to the mentor's influence, as measured by the mentors' BCCAI or IPI scores, also showed an influence on behaviors and attitudes. Using mentors' scores at Time 1 to predict the BCCAI or IPI scores of fellows at Time 3, the regression model fits were significant: BCCAI, adjusted $R^2=0.499$, $F(1,70)=71.77$, $p<0.001$; IPI, adjusted $R^2=0.129$, $F(1,92)=14.42$, $p<0.001$, respectively.

Hypothesis 4 was that ID-SURE fellows would display greater shifts toward transdisciplinary activities and values and achieve higher levels of integrative quality in their research products (final summer research projects) compared to those students in the fellowship programs who were not exposed to the interdisciplinary training curriculum. A 10-point scale was used for judging the integrative quality of the final summer research projects.[d]

Between-groups analyses comparing ID-SURE fellows and nonfellows found no significant differences between either the integrative quality of the final projects or the IPI. Interdisciplinary behaviors, on the other

[c]Variables and covariates were checked for homoskedasticity in terms of homogeneity of variance and homogeneity of covariance. Homogeneity of regression was examined by evaluating whether within-group regression coefficients for any covariates were equivalent. For example, linear relationships within and across groups were evaluated for correlations among standardized residuals for variance inflation factor and tests of correlations between errors (e.g. Durbin–Watson tests). Values missing at random were replaced using a regression, linear-trend-at-point estimate.[17] Screening for outliers was achieved using diagnostic procedures available in statistical packages such as SPSS. Listwise outlier values were Windsorized[18] to preserve data. For all regression tests including those of moderators, centered variables were computed for variables in the regression equations and other statistical models.

[d]No significant differences were expected or found in the intellectual quality of the projects, among the two comparison groups. Since fellows in both groups were recruited based on their GPAs and the quality of their proposals, it was expected that students in both groups would have achieved high levels of academic and intellectual achievement.

hand, were greater in the ID-SURE group. Fellows exposed to the ID-SURE program (M=4.8) showed increased interdisciplinary activities as measured by the BCCAI by the end of the training program compared to nonfellows: M=3.4, $F(1,117)=28.13$, $p<0.001$.

Hypothesis 5 was that ID-SURE training developed in students a transdisciplinary orientation toward working in teams and an appreciation of interdisciplinary concepts and methods. The TPPS, SCS, and the IDSAI were all positively associated with the BCCAI, as shown in Table 2. Further, the TPPS, SCS, and IDSAI at Time 1 all significantly predicted the BCCAI at Time 3, $p<0.001$. The LIS did not predict changes in interdisciplinary behaviors.

Qualitative Analyses

Whereas measures of team participation, social climate, laboratory impressions, and appreciation of interdisciplinary science were indirect measures of attitudes that could predict future involvement in interdisciplinary research careers, qualitative focus group interviews revealed more about future intentions of the ID-SURE students.

An important theme that emerged from the qualitative interviews was that working in a multidisciplinary team is enjoyable. This finding is consistent with the positive and significant correlation of the TPPS and the process measures of interdisciplinary perspectives and attitudes found in the quantitative analyses.

In addition to the opportunity to interact with students from different majors and learn about fields other than their own, students appreciated the lectures on interdisciplinary theories, research methods, and ethics. When asked about the things they learned from the ID-SURE program, several students commented that the experience "broadened their view of science," "opened their mind to new horizons," and allowed them to "look at a problem from other viewpoints." Several students expressed their interest in working as part of an interdisciplinary research team or on collaborative projects in the future. These findings corroborate the significant cumulative impact of the training program on students' interdisciplinary perspectives and behaviors, as evidenced by the longitudinal survey data.

Discussion

This study offers evidence for the efficacy of the ID-SURE program for training undergraduate students in transdisciplinary concepts, methods, and skills that are needed for effective scientific collaboration. A positive relationship was found between the Interdisciplinary Scientific Appreciation Index (IDSAI) and the TPPS. It is not clear whether appreciation of interdisciplinary collaboration preceded, or resulted from, students' participation in the collaborative team project. However, interview results suggest that working as part of a team was an influential and valued part of the ID-SURE curriculum. These findings suggest that interdisciplinary training programs should incorporate team projects as a required curricular component, at least for those programs geared toward undergraduate students.

This study contributes to the development and evaluation of interdisciplinary health research training programs in several respects. First, it presents and evaluates a novel curriculum for training undergraduate students in interdisciplinary theories, concepts, and methods of health promotion that can be replicated in other settings and contexts. Second, it provides and tests the reliability of new measures for evaluating interdisciplinary collaborative processes, including the BCCAI, the IPI, the TPPS, the LIS, the SCS, and the IDSAI. In addition, objective criteria for rating the integrative and intellectual quality of students' research products were developed and evaluated as outcome measures of interdisciplinarity. These product measures can be used in future studies to assess the effects of curricular or other training strategies that are intended to strengthen transdisciplinary research orientations and scientific collaboration.

Notably, students participating in the ID-SURE program effectively increased the frequency of their interdisciplinary collaborative activities, as measured by the BCCAI scale over the course of the training program. The ID-SURE fellows were also compared with non–ID-SURE fellows on the BCCAI measure. Results showed that interdisciplinary collaborative behaviors were significantly higher among the former group at the conclusion of the fellowship period. Thus, the ID-SURE curriculum appears to have been effective at instilling interdisciplinary perspectives that in turn led to a greater frequency and variety of interdisciplinary behaviors.

No significant differences were found between ID-SURE fellows and nonfellows on the IPI at the conclusion of their training period or in the integrative quality of their research products. This finding raises important questions, such as whether the nonfellows had an informal, unstructured interdisciplinary experience during their fellowship. A substantial number of nonfellows were engaged in research with mentor/s in disciplines other than their own. The interaction between the mentors and fellows may have encouraged interdisciplinary perspectives that were reflected in the final projects of the nonfellows.

Whereas ID-SURE fellows had the experience of engaging in some interdisciplinary collaborative behaviors such as participating in an interdisciplinary team project, reading articles outside their major, and attending lectures in other disciplines, the nonfellows were not exposed to those curricular opportunities. This difference might explain the significant differ-

ences in collaborative activities but not in interdisciplinary perspectives and inter-rater assessments of the integrative quality of research products, among participants in ID-SURE relative to those in the other fellowship programs.

A significant positive relationship was found between mentor interdisciplinary perspectives and behaviors and those of their fellows. In terms of both attitudes (e.g., interdisciplinary perspectives) and actual behaviors (e.g., indexes of behavior change), fellows appear to model their mentors. These findings highlight the substantial influence of scholarly role models on the development of students' research orientations and activities. Thus, the two facets of the ID-SURE training program that were found to exert greatest influence on the development of students' collaborative research skills and transdisciplinary orientations were their faculty mentors and their participation in a collaborative interdisciplinary team project over the course of the fellowship period.

This study was designed to elucidate the processes and outcomes of a new curriculum strategy designed to promote interdisciplinary research orientations and behaviors in undergraduate scholars. Whereas further research is required to better understand the components of an effective interdisciplinary training program, the findings from this study provide a conceptual and empirical foundation for that inquiry.

We gratefully acknowledge support for this manuscript provided by the NIH Roadmap Interdisciplinary Training Grant No. 15R13DK69500-03. We would also like to thank the two anonymous reviewers and the editor-in-chief for their helpful comments on an earlier version of this paper.

No financial disclosures were reported by the authors of this paper.

References

1. National Academy of Sciences. Facilitating interdisciplinary research. Washington DC: The National Academies Press, 2005.
2. Lattuca LR. Creating interdisciplinarity. Nashville TN: Vanderbilt University Press, 2001.
3. Nash J. Transdisciplinary training programs: key components and prerequisites for success. Am J Prev Med 2008;35(2S):S133–S140.
4. Nash JM, Collins BN, Loughlin SE, et al. Training the transdisciplinary scientist: a general framework applied to tobacco use behavior. Nicotine Tob Res 2003;5:S41–S53.
5. Stokols D, Hall KL, Taylor B, Moser RP. The science of team science: overview of the field and introduction to the supplement. Am J Prev Med 2008;35(2S):S77–S89.
6. Younglove-Webb J, Gray B, Abdalla CW, Purvis Thurow A. The dynamics of multidisciplinary research teams in academia. The review of higher education 1999;22:425–40.
7. Rosenfield PL. The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. Soc Sci Med 1992;35:1343–57.
8. Mitrany M, Stokols D. Gauging the transdisciplinary qualities and outcomes of doctoral training programs. J Plan Educ Res 2005;24: 437–49.
9. Klein JT. Crossing boundaries: knowledge, disciplines, and interdisciplinarities. Charlottesville VA: University of Virginia Press, 1996.
10. Stokols D, Harvey R, Gress J, Fuqua J, Phillips K. In vivo studies of transdisciplinary scientific collaboration: lessons learned and implications for active living research. Am J Prev Med 2005;28(2S2):202–13.
11. Stokols D, Misra S, Hall K, Taylor B, Moser R. The ecology of team science: understanding contextual influences on transdisciplinary collaboration. Am J Prev Med 2008;35(2S):S96–S115.
12. Cohen J. A coefficient of agreement for nominal scales. Educ Psychol Meas 1960;20:37–46.
13. Cronbach LJ. Coefficient alpha and the internal structure of tests. Psychometrika 1951;163:297–334.
14. Hall K, Stokols D, Moser R, et al. The collaboration readiness of transdisciplinary research teams and centers: findings from the National Cancer Institute TREC baseline evaluation study. Am J Prev Med 2008;35(2S): S161–S172.
15. Stokols D, Fuqua J, Gress J, et al. Evaluating transdisciplinary science. Nicotine Tob Res 2003;5:S21–S29.
16. Osgood CE, Suci G, Tannenbaum P. The measurement of meaning. Chicago: University of Illinois Press, 1967.
17. Schafer JL, Olsen MK. Multiple imputation for multivariate missing-data problems: a data analyst's perspective. Multivariate Behav Res 1998;33:545–71.
18. Tukey JW. The future of data analysis. Ann Math Statist 1962;33:1–67.