Afterword

Interdisciplinary and Team Dynamics

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Introduction

The U.S. National Science Foundation (NSF) has been attempting to foster the formation of interdisciplinary teams by funding research projects under the Biocomplexity in the Environment Competition (NSF 2003). The goal of NSF's program overlaps with the Border Plus Twenty Years (B+20) Project. That goal is to understand "...the complex interdependencies among living organisms (including humans) and the environments that affect, sustain, and are modified by them" (NSF 2003). Environmental biocomplexity research requires that the following be recognized:

- The high degree of complexity and uncertainty associated with human-environment interactions
- The interplay of interactions within and between different environmental systems
- That regulatory and management decisions must be made regarding systems where data and functional relationships are both uncertain and sparse
- The broad range of spatial and temporal scales
- The multiple levels of biological organization

Because many problems currently facing humanity bear these attributes (including human-environment interactions at the U.S.-Mexican border), NSF wants to improve the ability to perform biocomplexity research by developing ways to improve interdisciplinary

research strategies, guide interdisciplinary team building, and foster the development of interdisciplinary skills in young researchers. The B+20 project team provides one example of the formation and function of an interdisciplinary team.

NSF (2003) recognizes that "[a]dvancing our understanding of the nature and role of biological complexity demands increased attention and new collaborations of scientists from a broad spectrum of fields—biology, physics, chemistry, geology, hydrology, statistics, engineering, computation, social sciences." It is becoming increasingly clear, however, that the academic researchers currently applying for, and winning, the research funds can benefit from learning how to frame, plan, and perform interdisciplinary research that integrates knowledge across a broad range of disciplines. For example, Salter and Hearn (1996) note that interdisciplinary projects may fail by evolving toward a group of loosely connected monodisciplinary studies that fail to achieve the intended interdisciplinary goals. One factor that inhibits interdisciplinary research is the lack of well-prepared interdisciplinarians. Klein (1990) suggests that the personality traits of such team members might include "...reliability, flexibility, patience, resilience, sensitivity to others, risk-taking, a thick skin, and a preference for diversity and new social roles." Thus, it is increasingly apparent that team members require fundamentally appropriate personality traits, in addition to both discipline-specific and interdisciplinary training, if interdisciplinary teams are to be successful.

The authors posit that various factors inhibiting the success of interdisciplinary projects can be captured in the concept of "interdisciplinary overhead." This concept is analogous to the "transaction costs" or effort incurred in choosing, organizing, negotiating, and entering into business contracts (Williamson 1985). Research projects with intrinsically high interdisciplinary overhead require a carefully planned and facilitated process that helps dissipate the overhead while projects with intrinsically low overhead are more likely to succeed with much less cost in terms of financial expense, personal energy, and human resources. Obtaining a better understanding of the interplay between factors that contribute to interdisciplinary overhead help frame, plan, and complete successful

interdisciplinary research projects. Factors that lead to high interdisciplinary overhead in the B+20 project include the following team attributes:

- Wide geographic distribution
- Drawn from multiple institutions
- Broad cultural diversity
- Differing native languages
- Multinational context
- Monodisciplinary personalities and foci
- Inexperienced in interdisciplinary research
- Selection by project administration that is external to the team
- Lack of full control over project planning and direction

Having defined the concept of interdisciplinary overhead, the authors suggest that high interdisciplinary overhead leads to low levels of "interdisciplinarity"—a non-measurable quantity that influences the likelihood for success of an interdisciplinary project. For example, low overhead leads to high levels of interdisciplinarity within the project team and greater likelihood for project success. A project with low overhead is initiated with a high degree of interdisciplinarity because the project team is self-selected through an intense proposal-writing process. By developing a strategy that counters the factors previously listed, the resulting low interdisciplinary overhead enables a team to rapidly build interdisciplinarity and deliver an integrated research product. At the other end of the spectrum, a project team with high overhead takes longer to build even a moderate degree of interdisciplinarity. By failing to overcome the interdisciplinary overhead, the high-overhead project team devolves to a group of monodisciplinarians involved in a loosely connected group of monodisciplinary projects. An intermediate case might represent the interdisciplinarity trajectory of a project team that employs a variety of good strategies for reducing interdisciplinary overhead, but cannot fully overcome the limitations imposed by the complexity of the project and the characteristics of the team members. The B+20 project team likely fits in the intermediate category, having declined from a very high value in the early stages of the project to a current low-to-moderate value.

To develop its modeling framework, the team has attempted to work across at least three significant boundaries: disciplinary, institutional, and sectoral. Each of these exchanges brings additional complications. In order to model the U.S.-Mexican border region, the team requires technical expertise from a variety of scientific disciplines. Developing an integrated model requires epistemological assumptions and activities that do not always match disciplinary expectations. Ultimately, the final product is unlikely to match the disciplinary demands faced by any team member. Team members also are drawn from multiple institutions, each with different governance structures and mandates. Finally, because the model is intended as a decision-support tool for use in this region, the team must cross from the academic sector into the infrastructure sector.

One approach to dealing with this complexity is to identify potential flashpoints (challenges associated with crossing traditional boundaries) and assign one person to coordinate each flashpoint. If possible, the person's technical expertise should match their assigned role. Key roles (in addition to a project leader) for this project include:

- Model Coordinator
- Team Process Facilitator
- Outreach Facilitator

It is generally not productive for one person to coordinate multiple flashpoints. It is reasonable to expect the project leader to facilitate one of the potential flashpoints. For example, in this case the project leader could serve as the model coordinator, team process facilitator, or outreach facilitator, as indicated by individual expertise. The project leader should not attempt to play all of these roles, however. If desired, facilitators/coordinators may be part of the research team unless the level of conflict among team members is such that it requires an outside party to facilitate productive interaction. The three or four people playing these roles must work together to ensure that they do not undermine each other's tasks. It is generally best if the people playing these roles remain stable over the course of the project. Because the B+20 project has multiple study locales, however, it may be more reasonable to work with a different outreach facilitator for each locale.

Ultimately, the B+20 project is focused on developing a better understanding of border urban ecosystems that include the human decision-makers, managers, and citizens that influence how the community nested within the ecosystem operates. Nilon, et al. (2003) suggest that to be effective, this understanding must be gained by not only the members of the project team, but by those living in, and making decisions about, the community. Furthermore, Harisson and Burgess (1994) suggest that developing an understanding of urban ecosystems requires the recognition that "understanding" is a participatory and deliberative process, not just a one-way exchange of facts and information about ecological, physical, and social systems between experts and the public. Although the B+20 project team has engaged stakeholders and decision-makers in several discussions that have influenced project framing and direction, team members have been slow to build a coherent process for fully engaging stakeholders and decision-makers in defining attributes of, and questions to be explored with, the system model. The project team's early tentativeness in developing the modeling concept, the lengthy period required to develop team interdisciplinarity, and their lack of experience in community engagement are key factors that have inhibited productive community engagement. Lessons learned from this experience, however, are leading the team to begin their focused work in the Mexicali-Imperial Valley community (located on the border of California and Baja California) by quickly building on existing community partnerships established by the B+20 outreach coordinator.

Stakeholder Engagement

The project team has struggled with the issue of how and when to engage with individuals, communities, businesses, and agencies holding a vested interest in and concern about the future of the border. For this project to make an impact on quality of life on the U.S.-Mexican border, models of the borderland human-environment dynamic must be accepted, viewed as useful, and exercised by stakeholders who have participated to varying degrees in model develop-

ment. To date, the project team has worked largely in isolation as members developed their systems thinking and modeling capacity in an interdisciplinary team context.

The first stakeholder meeting was held at the Hilton Hotel in El Paso, Tex., on May 15, 2001. This meeting coincided with a working meeting of the project development team. It was not originally intended to be a stakeholder meeting so much as an opportunity for the project team to meet with a select group of community representatives to plan the stakeholder involvement process. Instead, the invitation list was expanded to include a broader group of community leaders and the meeting evolved into a *de facto* stakeholder meeting. Twenty-four individuals, in addition to the members of the project team, participated in the meeting.

The meeting began with a luncheon, during which a presentation was made to introduce attendees to the project. Following the luncheon, participants were invited to a separate workroom and introduced to the STELLA® program through an example from the land use and transportation sector that illustrated the effect of feedback loops. Subsequent discussion was prompted using three questions:

- Who could use this model?
- How do we involve stakeholders?
- What should we include or not include in the model?

Users of the Model

Initially, responses to the question about who could use this model generated the expected list of utility agencies, irrigation districts, resource management agencies, regional planning agencies, municipal land use and transportation planners, foundations, business advocacy organizations, and non-governmental organizations (NGOs). One person suggested that the research team might develop a matrix of potential users for dissemination. Although participants were intrigued by the possibility that B+20 could be a tool to break down institutional barriers within the community and thereby promote political understanding, participants were doubtful that lawmakers and other high-level policymakers would directly use the model. Rather, if the B+20 model is to become a viable decision-

support tool, participants suggested that the emphasis should be placed on making the model available to support staff of policymakers.

One participant suggested that the B+20 model might find value not as a decision-support tool but as an educational support tool. The potential value of the model for educational purposes was previously unrecognized. If this option is pursued, it will influence the nature of the model and the types of user interfaces provided in the computer program.

Some participants voiced concerns that the value and application of the model would be limited if direct access to it were restricted to the research team. Instead, participants advocated for the B+20 model to be designed to enable individual users to modify program parameters to meet their needs and interests. This generated further discussion of the workability of this approach—it was determined that it would limit users to those entities that were able to procure the software program.

Involving Stakeholders

Participants expressed the opinion that the model's acceptance requires active involvement of people and organizations, and thus they emphasized the need for more outreach efforts. Three general principles were suggested as a result of the discussion:

- The research team should seek a "buy-in" of the B+20 modeling effort from the intended users of the model, from the inception of the model development process
- The model's subsequent development should be influenced by the needs and potential applications of the stakeholders
- Stakeholders must have both an active and continuing involvement in the model's development to establish and maintain their trust

Several participants expressed opposition to the creation of a new group to provide stakeholder feedback. Instead, they suggested that the B+20 research team use existing organizations to promote stakeholder involvement. A concern was raised that fewer organizations might be available on the Mexican side of the border, but another

stakeholder observed that increasing levels of community involvement have changed the political landscape in Mexico. One participant stated that formal stakeholder meetings might be premature; he suggested that the research team first have one-on-one meetings with potential stakeholders and then bring the different stakeholders together in a formal meeting. He further noted that outreach efforts might involve a large number of participants, but input regarding individual sectors should be limited to small groups. Different applications of the B+20 model will require different approaches to stakeholder involvement. For example, if the educational support potential of the model is to be realized, an effort should be made to identify users in local universities and high schools.

Elements to Include in the Model

The ultimate development of the B+20 model will depend on the types of questions addressed by the model. Thus, identifying the necessary model elements and their relationships to each other is of importance only relative to the intended uses of the model. Despite this seemingly straightforward logic, the types of issues that might be analyzed by the model cannot be anticipated without first being assured that the basic model structure encompasses topics important to community leaders. Therefore, a final portion of the stakeholder discussion focused on the completeness of the list of elements previously identified by the research team, because this list forms the backbone structure of the model. The question put to stakeholders was simply stated as, What should we include or not include in the model?

The discussion of additional elements that might be included in the model actually commenced prior to the workroom discussion session. During the luncheon portion of the meeting, a participant made an impassioned plea to expand the model to include a separate housing sector. Comments from other participants indicated a broad consensus that housing quality is directly related to the quality of life of border inhabitants. Issues of concern include both the adequacy of supply and the quality of housing. Conceptually, inadequate housing supply results in overcrowding, whereas excessive

supply may cause abandonment and have a blighting influence on a community. Housing quality might be quantified by classifying housing either as meeting standards or as substandard. This simple division, however, may not be adequate to determine the magnitude of investment required to rehabilitate substandard housing if a significant percentage of a community's housing is severely substandard. Integrating housing with other sectors of the model poses different challenges. Housing demand is a factor of population change, but, more directly, the number of housing units required depends on a community's social composition, as this determines average household size. This level of detail is not currently built into the population sector. Similarly, housing demand is influenced by economic conditions. If new employment opportunities are predominantly low-wage, a growing community is more likely to have a lack of affordable housing, and this, in turn, could lead to an increase in substandard housing and overcrowding. The economy sector may not be sufficiently developed to project wage levels.

During the workroom discussion, participants expressed interest in better identifying crossborder links. They noted that investment in a city on one side of the border has an effect on its twin city on the other side, and thus an important, though seldom acknowledged, functional integration exists. The nature and, more importantly magnitude, of such economic links are neither well understood nor broadly appreciated. In this same regard, participants expressed interest in using the model to better identify transborder links on environmental issues such as air quality and water supply, and the implications of continued manufacturing growth on the region's energy demands. The economic future of the region will be affected by expected increases in north-south and east-west commerce, and therefore the regional economy is highly subject to external influences. Participants suggested that such external drivers be built into the model.

Several participants expressed a desire for a spatial element in the B+20 model. Initially this question was framed simply as, "What will El Paso look like in 20 years?" One individual commented that even energy issues might have a spatial component. During this portion of the discussion, the research team articulated the limitations of the current modeling approach. Because it lacks an explicit spa-

tial component, the first version of the model will not be able to address issues such as the distribution of poverty-stricken neighborhoods or the potential expansion of city limit boundaries. The research team offered that a spatial component might be incorporated if the project were funded for a second phase of development.

Another subject of discussion was the need to include cost parameters in the model. For example, participants stated that future sources of water would depend, in part, on the cost of water. One participant observed that identifying water sources alone would not account for cost implications because significant delivery infrastructure enhancements would be required if Ciudad Juárez, Chih., opted for a centralized water treatment system. Other participants voiced the opinion that the substantial subsidizing of water infrastructure in the region results in economic inefficiencies; this led to a discussion about using the model to project economic dislocations if water were to be priced based on its true cost. This concept, by itself, has no meaning unless significant institutional changes were adopted to create an open water market.

One of the concerns expressed by meeting participants was that the model should account for cultural differences between the United States and Mexico. This general need was expressed without being well-articulated. System dynamics can be used to model so-called soft variables, but doing so requires an explicit understanding of the nature and effect of such variables. In subsequent discussions, a member of the research team noted that some elements, such as legal implications, might not be capable of being modeled.

Climate change may affect the border region. One participant speculated that more water might be lost to evaporation and that prolonged periods of high temperatures could result in increased energy consumption by air conditioners. Another participant suggested that changes in the level of precipitation could alter daytime humidity, thereby lessening the efficiency of evaporative air conditioners. This would force a change in the type of air conditioning technology commonly employed in the region, with implications for both water use and energy demand.

A participant noted that the model was missing a rural sector. Rural elements include agriculture and potential sources of groundwater. In the latter instance, outlying rural communities have

already begun to express concerns over the effect of proposed groundwater import schemes by the large urban areas. The lack of a rural component, if deemed a significant deficiency, could challenge the basic structure of the model, as it has been fundamentally conceived of as a series of urban models.

The proposed 20-year timeframe may not be appropriate for all sectors of the model. The kinds of capital-intensive improvements required to meet the region's water needs may require adopting a 50-year timeframe to be consistent with the time horizon of current water plans.

The second stakeholder meeting was conducted at the offices of the Instituto Municipal de Investigación y Planeación (IMIP) in Ciudad Juárez on October 10, 2001. The meeting at IMIP coincided with a change of administration in Ciudad Juárez, and this conflict decreased the number of participants. Nonetheless, 27 people participated in the meeting and a number of different ideas were generated by the discussion. Participants were challenged to identify potential applications for the B+20 model and to speculate about the kinds of risks that might be involved in using it. Key issues discussed are detailed below.

Accessibility of the Model

One of the first questions raised concerned gaining access to the model once developed. Some participants expressed interest in having direct access to the model rather than having to go through the research team. Other participants suggested that complete copies of the model might be available to some key stakeholders, and a more limited version of the model might be available to the general public via the Internet. Both suggestions raise issues about software-licensing requirements and challenge the modeling team to develop a user-friendly interface to simplify the use of the model by local stakeholders.

Beyond gaining access to the model, participants expressed the desire that it be adaptable for a wide variety of potential users. Anticipating the needs of different kinds of organizations requires that flexibility be built into the model so that different users can adapt it for different applications. Another participant observed

that one benefit of the model was its use as a mechanism to prompt discussion among different agencies. This participant speculated that such a mix of agencies might include the Comisión Federal de Electricidad (CFE), the Junta Municipal de Aguas y Saneamiento (JMAS), and U.S. and Mexican environmental regulators.

Risks in Using the Model

Challenged with articulating their reservations about the potential misuse of the B+20 model, participants identified the following concerns:

- It will be challenging to create a model that is, at once, pertinent to real needs and issues, practically feasible to develop, and accurate and reliable in its projections
- If the model is to be accepted, all assumptions about the relationships of different elements must be clearly communicated and made available to prospective users
- There is a risk that some factors that exert a strong influence on the system may be omitted; for example, participants noted that none of the sectors included wastewater collection, treatment, and disposal options (i.e., agricultural use versus municipal reuse)
- The model should not promise more than it can deliver, or the expectations of prospective users will not be met; this may damage the credibility of the modeling effort
- The model may become too theoretical and thus lack any practical application

Model Validity Concerns

One of the concerns expressed during the meeting involved reliability. Similar kinds of information might be obtained from different sources but differences in the data should be reconciled before being included in the model. The formulae that connect different elements should be validated through some process, perhaps using historical data. Stakeholders offered that the relationship between different elements is likely to be complicated and non-linear.

Standardization of information on the two sides of the border is going to be a significant challenge. Stakeholders noted that some critical data might be unobtainable because they are deemed classified by the agency that possesses it. Because access to information from government agencies is different in Mexico than in the United States, stakeholders expressed concern that the lack of compatible information may make it difficult to create a symmetrical model that captures the dynamics of both communities with equal accuracy.

Land Use Concerns

Urban planners expressed interest in being able to use the model to test assumptions about the impact of different densities of development and different patterns of urban land use. In particular, one stakeholder suggested that, if new development could be guided to promote village-like nodes of commercial activity interspersed in the community and linked by mass transit, it could reduce traffic congestion and promote stronger neighborhood identity, thereby decreasing crime. Another stakeholder, who suggested the model be used to evaluate alternative scenarios about the direction of urban expansion, posed a similar challenge. These levels of analysis may be beyond the capabilities of the model currently under development. If the model is ultimately expanded to address such issues, it will have to incorporate a spatial aspect, perhaps by linking it to a geographic information system (GIS) program.

Economic Concerns

Stakeholders suggested that a structural analysis of the regional, binational economy was needed to determine the relative importance of different economic sectors. Such an analysis might document the relationship of different kinds of business activities to the number of people employed and the total employee payroll. In particular, some stakeholders were interested in identifying the levels of income associated with different types of businesses and industries.

One of the stakeholders maintained that the economy of Ciudad Juárez was too dependent on maquiladoras, and that this has created economic vulnerability. Further, the economic downturn in the United States resulted in the loss of approximately 60,000 maquiladora jobs in Ciudad Juárez in as many months. (Between January 2001 and November 2001, industrial employment in maquiladoras throughout Mexico declined by 206,636 people, representing a nearly 16% reduction [INEGI 2002]). Another stakeholder suggested that the layoffs at maquiladoras were responsible for a recent increase in the city's crime rate. To diminish the vulnerability of the local economy, programs are needed to diversify the region's economy. Stakeholders suggested that the model be designed to allow analysis of the broader implications of different economic diversification schemes.

One stakeholder posed the rhetorical question, What if there were no border? This generated subsequent discussion of incorporating features into the model that could explore the implications of changes in the operations at the international ports of entry. Potential issues that were suggested included altering waiting times, changing immigration policies, and modifying import restrictions.

Qualitative Data Concerns

Several stakeholders expressed a desire for more social elements in the model. Specific suggestions included:

- Public health indicators, such as the incidence of different types of disease
- Public service availability, such as the extent of coverage of water service, wastewater service, health service, and variable levels of hygiene
- Education, such as the level of educational attainment of the existing population and the adequacy of the two communities' educational facilities and programs
- Crime rates, especially when variations in crime rates can be associated with economic perturbation, or with recentness of household tenure (such as when neighborhoods have a large percentage of recent in-migrants)

Stakeholders also challenged the modeling team to incorporate differences, on either side of the border, of political and economic systems, as well as the subtler cultural differences. Because cultural issues are inherently qualitative, it will be difficult to integrate such elements into the model. In subsequent discussions, stakeholders speculated that if the criteria used to select qualitative information were not carefully chosen, it could alter the model's operation, color the interpretation of its results, and ultimately influence the types of users.

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