

**A longitudinal panel study of participants' attitudes and behaviors towards transdisciplinary science**

by

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A thesis submitted to the graduate faculty  
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Sustainable Agriculture

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2015

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## TABLE OF CONTENTS

	Page
LIST OF TABLES .....	vi
LIST OF FIGURES .....	vii
ACKNOWLEDGEMENTS .....	viii
CHAPTER 1. GENERAL INTRODUCTION .....	1
Introduction.....	1
Thesis organization.....	3
Literature Review.....	3
Defining levels of collaboration.....	3
Common characteristics of transdisciplinary science .....	6
Transdisciplinary benefits and challenges .....	7
Transdisciplinary evaluation.....	11
Graduate student participation in transdisciplinary science.....	13
REFERENCES .....	16
CHAPTER 2. CHANGES IN PARTICIPANTS' PERCEPTIONS OF TRANSDISCIPLINARY SCIENCE OVER TIME .....	20
Abstract.....	20
Introduction.....	21
Overview of transdisciplinary science .....	21
The potential benefits of transdisciplinary science .....	23
The potential challenges of transdisciplinary science.....	24
Paper Overview.....	25
Research on Transdisciplinary Science .....	26
Evaluation of transdisciplinary projects.....	26
Conceptual background and framework .....	29
Research objectives.....	32

Materials and Methods.....	33
Climate and Corn-based Cropping Systems	
Agricultural Project (CSCAP) .....	33
CSCAP participants .....	35
Survey sample.....	39
Measures .....	40
Transdisciplinary attitudes .....	41
Collaborative behaviors .....	42
Satisfaction with collaboration .....	43
Impact of collaboration.....	43
Trust and respect.....	44
Summated scales.....	45
Participant roles .....	45
Analysis.....	46
Analytical approach .....	46
Results.....	46
Transdisciplinary attitude.....	47
Collaborative behavior.....	48
Satisfaction with collaboration .....	49
Impact of collaboration.....	50
Trust and respect.....	51
Discussion.....	52
Transdisciplinary attitudes .....	52
Collaborative behaviors .....	53
Satisfaction with collaboration .....	53
Impact of collaboration.....	54
Trust and respect.....	54
Conclusion .....	55
REFERENCES .....	58

## CHAPTER 3. DETERMINANTS OF PARTICIPANTS' PERCEPTIONS TOWARDS

TRANSDISCIPLINARY SCIENCE OVER TIME .....	64
Abstract.....	64
Introduction.....	65
Transdisciplinary overview.....	65
Transdisciplinary science-potential benefits.....	67
Transdisciplinary science-potential challenges.....	68
Paper overview.....	69
Research on Transdisciplinary Science .....	70
Evaluation of transdisciplinary projects.....	70
Conceptual background and framework .....	72
Project description: Climate and Corn-based Cropping Systems	
Coordinated Agricultural Project (CSCAP).....	74
CSCAP participants .....	76
Survey sample.....	80
Research objective .....	81
Methods.....	83
Measures .....	83
Transdisciplinary attitudes .....	84
Collaborative behaviors .....	85
Satisfaction with collaboration .....	86
Impact of collaboration.....	87
Trust and respect.....	88
Participant roles .....	88
Gender.....	89
Analysis.....	89
Analytical approach .....	89
Change score creation.....	89
Results.....	91
Changes in TD attitude: behavior and collaboration scales.....	92
Changes in TD attitude: participant roles .....	92

Discussion .....	93
Trust and respect .....	93
TD attitude and role .....	94
Conclusion .....	95
REFERENCES .....	98
CHAPTER 4. GENERAL CONCLUSION .....	104
Conclusion .....	104
Implications.....	106
Limitations and Future Directions .....	107

## LIST OF TABLES

	Page
Chapter 2:	
Table 1. Transdisciplinary attitudes items: Individual survey items .....	41
Table 2. Transdisciplinary behavior items: Individual survey items .....	42
Table 3. Satisfaction with collaboration: Individual survey items .....	43
Table 4. Impact of collaboration: Individual survey items .....	44
Table 5. Trust and respect: Individual survey items .....	44
Table 6. Percentage distribution of project participants by role .....	46
Table 7. Results for CSCAP evaluation measures .....	47
Chapter 3:	
Table 1. Seven generic principles of transdisciplinary evaluation. ....	71
Table 2. Transdisciplinary attitudes: Individual survey items .....	85
Table 3. Transdisciplinary behavior: Individual survey items.....	86
Table 4. Satisfaction with collaboration: Individual survey items .....	87
Table 5. Impact of collaboration: Individual survey items .....	87
Table 6. Trust and respect: Individual survey items .....	88
Table 7. Transdisciplinary scale results for collaborative behaviors and TD..... integration measures .....	90
Table 8. Linear model of predictors of TD attitude change.....	91

## LIST OF FIGURES

	Page
Chapter 2:	
Figure 1. CSCAP Conceptual Model.....	30
Figure 2. CSCAP Project: Transdisciplinary science model .....	34
Figure 3. Transdisciplinary attitudes: Change over time (2011, 2013) for CSCAP team and subgroups.....	48
Figure 4. Collaborative behavior: Change over time (2011, 2013) for CSCAP team and subgroups.....	49
Figure 5. Satisfaction with collaboration: Change over time (2011, 2013) for CSCAP team and subgroups .....	50
Figure 6. Impact of collaboration: Change over time (2011, 2013) for CSCAP team and subgroups.....	51
Figure 7. Trust and respect: Change over time (2011, 2013) for CSCAP team and subgroups.....	52
Chapter 3:	
Figure 1. CSCAP Conceptual Model.....	73
Figure 2. CSCAP Project: Transdisciplinary science model .....	75
Figure 3. Mean change in TD attitude .....	94

## ACKNOWLEDGEMENTS

I would like to take this opportunity to express my gratitude to my committee members who have assisted me with the research and writing of this thesis. First and foremost, I would like to thank Dr. J. Gordon Arbuckle who guided me through this process with patience, encouragement, and a great knowledge of academic writing. The skills I gained through his mentorship will guide me throughout my career. I would also like to thank Dr. Eugene Takle who was instrumental in my decision to pursue my degree and whose support, encouragement, and advice has had a profound impact on my academic journey. I am also very grateful to Dr. Michael Dahlstrom for his guidance in academic writing, and whose great expertise in science communication has been an inspiration. I would also like to extend my gratitude to Dr. Lois Wright Morton and the rest of the CSCAP leadership team for the opportunity to be involved in such an important project. Finally, I would like to thank my family for all their encouragement and support throughout this process.



## CHAPTER 1.

## GENERAL INTRODUCTION

**Introduction**

The scientists of today and tomorrow are exploring scientific territory that is becoming increasingly complicated, in part due to our expanding knowledge of the interconnectedness of the world. With this complexity come great challenges and opportunities for the scientific community. Disciplinary research has provided immeasurable gains in knowledge and continues to have an important place in science advancements. However, there are a growing number of research questions that cannot be answered within disciplinary boundaries. These questions require the scientific community to converge outside of their designated fields of study to examine issues from a variety of perspectives. The goal of this team science model is to produce effective outcomes to research questions and propel scientific discoveries beyond the boundaries and narrow focus of disciplinary efforts.

Team science is gaining momentum not only in the academic arena, but also with funding agencies, which are important actors in guiding research interests. The varying levels of collaboration within the field of team science have provided an important dialogue to help define this new method of scientific exploration. Over the years, collaborative differences have at times been miscommunicated. Interdisciplinary, multidisciplinary, and transdisciplinary efforts were often used interchangeably in the early stages of developing the foundation for collaborative science. Now, decades later, we have an established framework

to guide the field of team science and offer researchers an opportunity to explore the effectiveness of collaborative research.

To that end, this paper explores the highest level of collaborative science, transdisciplinary research. It offers an extensive literature review to provide background information on this emerging field of study and to identify gaps in the research that subsequent chapters hope to address. There is a growing body of research dedicated to learning more about the opportunities and barriers to transdisciplinary research, as well as representative characteristics of effective transdisciplinary research, and the evaluation process. However, there are substantial gaps in our knowledge. In particular, little quantitative research has focused on understanding the experiences of the participants. This study uses evaluation data from the Climate and Corn-based Cropping Systems Agricultural Project (CSCAP). The CSCAP is a large, five year transdisciplinary project created to examine the impact of climate on corn production. A participant evaluation survey provided the data to examine the following research questions:

- 1) Do participants' attitudes and behaviors toward the transdisciplinary process change over the course of the project?
- 2) Do these changes vary by participant role?
- 3) What factors are associated with changes in attitudes toward transdisciplinary research over time?

**Thesis organization.**

This thesis is organized as four chapters. The first chapter serves as an overview of transdisciplinary science based on an extensive literature review. Research relevant to this study will be drawn from the literature review in the first chapter to emphasize key elements in our study. This chapter also outlines two research questions that will be addressed in subsequent chapters. Chapter Two, “Changes in participants’ perceptions of transdisciplinary science over time,” is a stand-alone paper, which analyzes the CSCAP evaluation data and presents results regarding research question one and two. Chapter Three, “Determinants of participants' perceptions towards transdisciplinary science over time”, is also a stand-alone paper, which analyzes the data and presents results regarding research question three. Chapter Four integrates the results of the CSCAP evaluation study with previous research and discusses the limitations of this study and the opportunities for future research in the area of transdisciplinary science.

**Literature Review**

This literature review was conducted to capture the full breadth of transdisciplinary research to date. Much of the research is reflected in Chapters Two and Three. However, as research questions were finalized, aspects of this broad search that were not specifically relevant to the objectives of this study were not included in subsequent chapters.

**Defining levels of collaboration.**

Within the field of team science there are varying levels of collaboration, which include research that is multidisciplinary, interdisciplinary and transdisciplinary. What drives the existence of the collaboration is an important consideration and will provide guidance as to the level of collaboration that is utilized. As Harris & Lyons (2013) explore, there are

academic-driven collaborations and issue-driven collaborations. Academic-driven collaborations are those that are driven by the desire to discover and occur often within discipline boundaries. Issue-driven collaborations are motivated by problem solving identified issues or threats. These collaborations are often transdisciplinary due to the complexity of the problem (Robinson, 2008).

The integrative research terms multidisciplinary, interdisciplinary and transdisciplinary are often used interchangeably, but there are subtle differences that are important for purposes of this paper. Authors Tress, Tress & Fry (2002) define the varying degrees of team science in the following way:

***multidisciplinary-*** projects that involve several different academic disciplines researching one theme or problem but with multiple disciplinary goals.

***interdisciplinary-*** projects that involve several unrelated disciplines in a way that forces them to cross subject boundaries to create new knowledge and theory and solve a common research goal.

***transdisciplinary-*** projects that integrate academic researchers from different unrelated disciplines and non-academic participants, such as land owners and the public, to research a common goal and create new theory and knowledge.

Transdisciplinary combines interdisciplinary with a participatory approach. Within the field of transdisciplinary science, there are varying degrees of engagement by project teams and individuals within the teams. At a team level, many transdisciplinary projects have tasks and goals that utilize disciplinary, multidisciplinary, and interdisciplinary processes, all under the overarching theme of transdisciplinarity. At the project level,

Mobjork et al. (2010) suggests two additional distinctions regarding the level of collaboration by non-academic partners: consulting and participatory transdisciplinary research. Consulting research refers to the involvement of non-academic partners in a consulting capacity. These partners are not involved in the actual research process. In participatory research, non-academic partners are involved in all aspects of the research process and are considered equal stakeholders.

Team collaboration can also be categorized by the analytical level that dominates the team (Stokols et al. 2003). In horizontal integration, multiple fields share the same analytical level (i.e. cellular, societal). In contrast, vertical integration is described as different analytical levels between the represented disciplines. Vertical integration is more challenging due to the multiple levels and perspectives, but has a higher potential to produce significant strategies (Stokols et al. 2003).

At an individual level, participant engagement can be categorized into the following levels: information, consultation, collaboration, and empowerment (Brandt et al. 2013). With each level, the amount of participation and engagement increases. At the information level, communication is one-way and limited. The consultation level adds responses to communication. Collaboration requires the participants to have an influence on the outcomes. At the highest level, decision-making authority is given to the participants. Although empowerment is considered the highest level of collaboration and a goal to strive for, few projects involve engagement with non-academic partners at the decision-making or empowerment level (Brandt et al. 2013).

Due to the complexity of the problems that transdisciplinary teams are tasked to solve, many are multi-year endeavors. It is possible during the course of the project that

collaborations, and levels of collaboration, will shift and change, either by design or naturally (Wright Morton et al. in process). All of the factors that need to be considered for project design and implementation make each project unique. Therefore, shifts and re-evaluations in the project will also be unique. Being prepared to assess and realign project goals throughout project implementation is referred to as the Architecture of Adaptive Integration (AAI) (Wright Morton et al. in process)

### **Common characteristics of transdisciplinary science.**

Despite common characteristics of transdisciplinary research, each transdisciplinary project will have its own unique structure as necessitated by its goals and objectives. There may not be a “one size fits all” model for transdisciplinary research, but some common structural features have been identified. First, transdisciplinary teams must be goal oriented (Wright Morton et al. in process). Secondly, transdisciplinary teams are diverse in nature (Stokols et al. 2008). They are composed of researchers in various academic roles, administrative participants, principal and non-principal investigators, graduate students, and non-academic partners. The various collaboration combinations are extensive and require effective communication (Cheruvilil et al. 2014). Disciplinary and cross-disciplinary clusters (Wright Morton et al. in process) are likely to form based on expertise and objectives. Thirdly, team collaborations are likely to be hybrids of various integrated research levels (Stokols et al. 2008). For instance, there are certain objectives that may remain more disciplinary in nature, under the broader umbrella of transdisciplinary research. Other objectives will cross disciplinary boundaries and require more interdependence, which is an important team characteristic (Cheruvilil et al. 2014). It is also important for teams to define boundaries and outcomes while creating an atmosphere that promotes innovation and

flexibility (Wright Morton et al. in process). Defining boundaries provides a framework to establish individual and group accountability (Cheruvilil et al. 2014). Finally, many of the larger transdisciplinary collaborations include participants who are geographically dispersed (Stokols et al. 2008). It is quite common for participants to be working on objectives with researchers at other institutions in different states. Strategies for continual assessment and adaptation (Wright Morton et al. in process) to keep teams on course and provide feedback on project awareness is especially critical when geographic barriers prevent consistent face-to-face meetings. However, when teams are not faced by geographic challenges, face-to-face meetings are important for effective communication and have been shown to increase publication rates, at least in the field of ecology (Hampton & Parker, 2011).

#### **Transdisciplinary benefits and challenges.**

Aside from the possible problem-solving benefits of collaborative science as a whole, there has been considerable debate on the potential costs and benefits to individual project participants. Collaboration across disciplines, institutions, and third-party interests is time intensive and it takes patience and commitment to establish trusting relationships. To outweigh the significant costs, the participants must view the experience as beneficial.

Most academic researchers are focused on publications as the institutions they work for have high expectations for published research. A possible benefit of collaborative research is an increase in publication rates (Porter et al. 2012). However, there have been conflicting studies on transdisciplinary research and the impacts on publications. Due to the cross-disciplinary nature of integrative research, there are few specific journals designated for this type of research. Teams must submit research to journals that traditionally have published discipline specific research. (Porter et al. 2012)

Another benefit of transdisciplinary science, especially for those participants in the earlier stages of their careers, is the greater visibility within the scientific community (Goring et al. 2014). The networking potential can produce benefits well beyond the scope of the project and provide intellectual companionship for researchers (Katz & Martin, 1997).

Additionally, previous participation in a collaborative project increases the probability of participation in a future collaborative project (Hampton & Parker, 2011). This not only benefits individuals for the reasons stated in this section, but having participants who have experience in transdisciplinary projects involved in future projects may improve the planning and implementing process and potentially increase successful outcomes.

Benefits that are important but not as easily measured are the professional relationships that are developed over the course of the project, the personal satisfaction from working on high impact projects, and the inspiration that can be gained from working in close collaboration with others (Goring et al. 2014).

There are existing tensions between the benefits of working across disciplinary boundaries to solve complex problems and the potential costs of such collaborations (Cummings & Kiesler, 2005). A challenge for transdisciplinary research as a whole is the lack of a consistent and coherent frame for the term transdisciplinarity (Brandt et al. 2013). Research seems to be gaining momentum, but the sheer numbers of terms being used for integrative research makes it difficult to quantify (Tress et al. 2005).

The majority of studies exploring the barriers to effective transdisciplinary science involve the collaborative process itself. A few studies offer unique perspectives, but one theme resonates: transdisciplinary research requires a collaboration of multiple disciplines and a melding of distinctive frameworks and methods (Brandt et al. 2013; Stock & Burton,



2011; Wright Morton et al. in process). This cooperation requires participants to merge knowledge, theories, ideas, and methods to create new ways to research and potentially solve complex problems. This presents a difficult task for all participants involved.

Moreover, the traditional research process requires that research be reproducible, a key element in proving or disproving hypotheses. Since each transdisciplinary research project is unique and builds methodologies based on the distinctive mix of disciplines and participants, the ability to reproduce the research is complicated, if not compromised (Brandt et al. 2013).

The collaboration of disciplines and methods also introduces new and alien language and a different knowledge base to those participants crossing disciplines (Stock & Burton, 2011). This creates barriers to communication that takes time, flexibility, and innovation to overcome. Studies have shown that trust among participants can help reduce barriers and create an environment where differing language and methodologies can coexist. (Harris & Lyon, 2013).

Collaboration across institutions poses significant challenges as well. For instance, project participants may be functioning on different school schedules, utilize differing software programs within their respective disciplines, or have differing, if not conflicting, contract requirements and procedures (Cummings & Kiesler, 2005). These “remote collaborations” (Stokols et al. 2008) also reduce face-to-face meeting opportunities. Face-to-face meetings have been found in numerous studies to foster communication, problem solving, and productivity (Hampton & Parker, 2011). Virtual meetings were not found to create the same positive environment for building trusting relationships (Wright Morton et al. in process).

Crossing geographic boundaries also presents infrastructure challenges. Researchers and/or institutions that are separated spatially cannot share resources and critical infrastructures (Stock & Burton, 2011). Therefore, ensuring that each project site has the necessary resources to complete research goals can require a significant financial investment.

Critics of team science often highlight the difficulty in proving its effectiveness. Benefits from project outcomes are sometimes not evident for years or decades (Stokols et al. 2008). This delay in achieving project outcomes is difficult for participants who wish to experience the satisfaction of moving science forward, and for funders who expect to receive evidence that their funding choices are appropriate and successful. For example, a study by Bruneel et al. (2010) explored barriers between university and industry collaborations. One such barrier was the concern over the lower sense of urgency for research outcomes at the university level compared to industry. Certainly with looming budget restraints and urgent matters to solve, investments in transdisciplinary science must be made strategically and efficiently (Stokols et al. 2008).

In addition, critics argue that dwindling funding is being transferred from disciplinary science to large multi-disciplinary projects, which have time limits. Specifically, the worry is that when transdisciplinary-specific funding is discontinued from a research group, institution, or research center, all the efforts and energy that went into that specific collaboration will not be sustained (Marks, 2006; Hall et al. 2008).

Despite the significant challenges identified for collaborative projects, it appears that integrative research continues to be the goal for complex problems facing the world today. While transdisciplinary research was just beginning to gain momentum in the scientific field, an article written by John Rapport (1997) encouraged readers to open their minds to the

possibilities of transdisciplinary research. He states, "...if we are to heed Herb Bormann's plea for changing the current philosophy of 'man apart from nature' to a 21<sup>st</sup> century philosophy of 'human kind a part of nature', then we must build bridges within and between the social, natural, and health sciences. The change is not merely academic. It may be a matter of survival."

### **Transdisciplinary evaluation.**

"Disciplinary and transdisciplinary research are coexisting parts of modern science which poses a challenge to research evaluation" (Kaufmann & Kastzler, 2009). Despite this challenge, evaluative studies for transdisciplinary research are necessary to demonstrate their effectiveness for ongoing financial and research support (Stokols et al. 2003). However, there are barriers to effective evaluation that are described in an article by Stokols et al. (2003). For instance, the hybrid nature of the research team creates complications for a standard and consistent evaluation process. Moreover, the evaluators of the integrative research endeavors are likely non-neutral parties. They are either involved in the project itself, or have a stake in the results. An additional barrier is determining the appropriate time frame to evaluate whether outcomes have been met. Due to the nature of the complex problems that transdisciplinary teams are confronted with, it can sometimes take years for results to be realized.

With the complexity of the issues in mind, most studies focus on the outcomes in the latter stages of the project. However, a study at the National Cancer Institute evaluated the collaborative-readiness of transdisciplinary projects. It explored characteristics of the Transdisciplinary Research Energetics and Cancer (TREC) initiative to assess the readiness of participants at the outset of the project (Hall et al. 2008). The authors of the study

uncovered several factors that they identified as collaboration-readiness factors that influence teamwork in the initial stages of transdisciplinary projects. The antecedent factors can be categorized into three groups: contextual-environmental, which addresses the infrastructure considerations such as institutional supports/barriers, environmental proximity, and electronic connectivity; intrapersonal characteristics which address research orientation and leadership qualities; and interpersonal factors which address group size, the variety of disciplines represented, and the researcher's histories in previous transdisciplinary projects. The authors argue that evaluation should occur throughout the project (Stokols et al. 2003), however, getting the project started in a positive direction by addressing antecedent factors is an important aspect of transdisciplinary research. Readiness levels can be reinforced through increasing antecedent conditions, but should remain flexible enough to account for all the variations in project integration (Klein, 2008).

A transdisciplinary research literature review by Klein (2008) revealed seven generic principles for transdisciplinary evaluation: 1) variability of goals, 2) variability of criteria and indicators, 3) leveraging of integration, 4) interaction of social and cognitive factors in collaboration, 5) management, leadership, and coaching, 6) iteration in a comprehensive and transparent system, and 7) effectiveness and impact.

Principle one, the variability of goals, is unavoidable in the context of transdisciplinary research given its merging of disciplines. Goals and objectives should be decided on as a team and evaluated as such. The authors of the study found that the variability of goals also drives the second principle: variability of criteria and indicators. Principle three, evaluating the quality of the transdisciplinary project has traditionally been measured through outputs such as patents, publications, citations and peer approval in the

scientific community. These indicators can also vary given the combination of disciplines involved in the project. The fourth principle, leveraging of integration, addresses the idea of evaluating the quality of the process. In other words, evaluating the integration process itself. Principle four addresses the intersection between the intellectual and social factors of integration. The authors found that intellectual integration is influenced socially through shared learning activities and mutual knowledge arises from this integration. Principle five addresses the evaluation of management and coaching. This principle calls for the evaluation of leadership, organizational structure, networking, and communication. Principle six addresses the importance of iteration to provide input opportunities, and transparency. Evaluating the feedback opportunities was found to be an essential element. Finally, principle seven addresses the evaluation of effectiveness and impact. If evaluators look solely to this principle to evaluate transdisciplinary projects, there is valuable information missing that can help guide new projects.

The diverse nature of transdisciplinary research provides challenges for evaluating this integrative science. Evaluative measures should take into account this diversity of the disciplines and participants, but also include the essential elements of evaluating scientific advancement, and education/training beyond the bounds of the project to translational and public-policy outcomes (Stokols et al. 2008).

#### **Graduate student participation in transdisciplinary science.**

Graduate students are in a distinctly difficult position. The contrasting goals of establishing themselves in their respective fields (Stokols et al. 2008) and participating in the growing field of team science can seem at odds. The current academic culture values certain research outputs over others, such as primary-authored publications, which can be

problematic for early-career researchers involved in collaborative research (Goring et al. 2014).

The next generation of scientists are being mentored and trained at universities all over the world. However, most training efforts are focused on single-investigator-driven science with little emphasis on formal teamwork training (Cheruvilil et al. 2014). Without this emphasis and focus in training the next generation of transdisciplinary researchers, the sustainability of transdisciplinary research is in question (Hall et al. 2008).

A possible outcome of transdisciplinary research is to provide training for graduate students to go on to fill top research jobs, and for undergraduates to earn graduate program positions. The most successful training programs outcomes were found with those projects that involved one university and only a few disciplines (Cummings & Kiesler, 2005).

However, the training provided for transdisciplinary research for graduate students can often be inconsistent. For instance, graduate students may be involved in multiple or evolving projects over the course of their studies and those studies could occur at more than one institution by the time graduate, and post-graduate studies are complete (Goring et al. 2014).

More qualitative and quantitative research is needed to assess the impact of various training programs and subsequent career paths of trainees in transdisciplinary programs (Hall et al. 2008). However, perhaps one of the largest impacts on the next generation of scientists comes from mentoring relationships with established scientists. Scientists are often focused on getting their research published, but transdisciplinary science provides an alternate route for making a difference in the scientific community. As Roux (2010) points out, “The effort and time taken to inspire students may leave a much bigger legacy than research papers they produce themselves.” However, the mentor and mentee relationship will involve participants

who are at different stages of their careers. Balancing contributions across these differing stages and recognizing possible constraints and opportunities is important (Goring et al. 2014).

Although the breadth of transdisciplinary research is growing rapidly, a gap for future research still remains. An important perspective that is often unnoticed is the role of the non-principal investigator (Stokols et al. 2003). Graduate students are a good example of this and can provide valuable insights into team development. One exception to this is the study conducted at Transdisciplinary Tobacco Use Research Center (TTURC) (Stokols et al. 2003). The TTURC project at UC Irvine conducts focus groups with non-principal investigators on an annual basis to measure the degree to which principal investigators are modeling and teaching a transdisciplinary ethic to their trainees (Stokols et al. 2003).

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## CHAPTER 2

CHANGES IN PARTICIPANTS' PERCEPTIONS OF  
TRANSDISCIPLINARY SCIENCE OVER TIME

A paper to be submitted to *Environmental Science & Policy*

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**Abstract**

Transdisciplinary research teams offer an appropriate alternative to traditional research methods to address today's complex research problems. However, a lack of common technical language and differing attitudes on collaborative research can create challenges. This paper reports results of an evaluative survey on changes of collaborative capacity within a large transdisciplinary project. Our survey data, collected through pre-assessment (2011) and mid-assessment (2013) evaluation surveys of project participants, measured participants' attitudes, behaviors, and beliefs regarding transdisciplinary research. Paired samples t-tests were employed to compare measures from the same individuals at two points in time. The key variables were transdisciplinary attitudes, transdisciplinary behaviors, satisfaction with collaboration, perceived impacts of collaboration, and trust and respect. Changes over time were evaluated for the overall project team and by project role subgrouping that included principal investigators, professional and technical staff, graduate

students, advisory board members, and extension educators. The analysis examined the following research questions: 1) Do participants' attitudes and behaviors toward the transdisciplinary process change over the course of the project? 2) Do these changes vary by participant role? Results indicate that while collaborative behaviors did not significantly change for most of the role subgroups, advisory board members showed a decrease in transdisciplinary behaviors from the pre-assessment to the mid-assessment evaluation. Analysis of the other measures consistently showed a positive increase in mean scores from the pre- to the mid- assessment with one exception. Graduate student scores on the transdisciplinary attitude scale decreased over time. Understanding how participant perceptions may change over the course of a project and how project roles may influence these changes is important to managing effective long-term transdisciplinary projects.

## **Introduction**

### **Overview of transdisciplinary science.**

The traditional role of scientific research has resulted in big names and breakthroughs (Wuchty, 2007). Names such as Newton and Einstein are singular individuals representing disciplinary roles that have propelled scientific discoveries to new levels. It is widely accepted that traditional, discipline-based research has contributed to immeasurable scientific advancements (Stock & Burton, 2011) and provided scientists with a common language and frame of reference (Petts, 2008). However, the last few decades have seen the development of new models of research that cross disciplinary boundaries in conceptualization and implementation (Wuchty, 2007; Kessel et al. 2008; Stokols et al. 2005; Stock & Burton, 2011). Collaborative methods for scientific research are increasing in importance as scientists

are tasked with researching the world's most complex problems. The complexity of these issues requires scientists to transcend their own disciplinary boundaries and create teams to assess the interconnected network of systems associated with the problem.

This synergistic approach, known as team science, is defined as a collaborative effort to address a scientific challenge that leverages the strengths and expertise of professionals trained in different fields. It is based on the assumption that organizing scientists across multiple fields of study to analyze and research complex problems will produce better scientific outcomes. Within the field of team science there are varying levels of collaboration. Integrative research can be multidisciplinary, interdisciplinary or transdisciplinary. Multidisciplinary refers to two or more separate disciplines working together, yet maintaining their own disciplinary perspectives and methods (Russell et al. 2007). Interdisciplinary refers to the integration of multiple disciplines towards setting common goals and developing integrated knowledge and theory (Tress et al. 2005). Transdisciplinary research (TDR) differs from multidisciplinary and interdisciplinary in that it integrates researchers from different, unrelated disciplines and non-academic partners, to research a common goal and create new theory and knowledge (Tress et al. 2002). It is generally an issue-driven collaboration, focusing on an identified issue or threat (Harris & Lyons, 2013; Robinson, 2008). It is guided by a "logic of accountability" whereby a wide range of participants, including stakeholders, have the opportunity to provide input that will ostensibly improve scientific relevance and accountability (Barry et al. 2008; Nowotny, 2001; Donaldson, 2010). In theory, this approach to research creates more feedback loops to guide research questions and outcomes.

Transdisciplinary research is conceptualized as the highest level of collaboration among scientists. Transdisciplinary research requires a collaboration of multiple disciplines and a melding of distinctive frameworks and methods (Brandt et al. 2013; Stock & Burton, 2011; Wright Morton et al. in process). It requires participants to merge knowledge, theories, ideas, and methods to create new ways to research and potentially solve complex problems (Stock & Burton, 2011; Brandt et al. 2013; Tress et al. 2002). This type of scientific integration can produce benefits, but there are challenges as well.

The remainder of this section examines the barriers and benefits of transdisciplinary research and why these integrated projects are important. The next section summarizes key literature, which provides some background information on key variables in this study. The statistical analysis used for this study is outlined in the Methods section, followed by a discussion of the results. Finally, a summary of the study and next steps are considered.

### **The potential benefits of transdisciplinary science.**

Transdisciplinary science is the collaborative target for many small and large research projects due to increasing optimism that the pooling of scientific knowledge can lead to a more comprehensive understanding of today's complex problems and their solutions. The participatory approach at the center of transdisciplinary science, which often combines experimental and applied research, has great potential to generate societal benefits. A growing number of funding agencies recognize the importance of this approach and are requiring research grants to include transdisciplinary teams to produce research outcomes. In addition, the National Institute of Health (NIH) has created multi-center initiatives intended to promote collaborative research and training (Hall et al. 2008).

These and other funding agencies, whether private or governmental, are under increasing pressure to produce research that will provide insights into some of our most pressing issues. Competition for diminishing research funds to address these complex issues provides an impetus for demonstrating the contributions of transdisciplinary research to society (Roux, 2010). To stay competitive, especially with large federally funded projects, scientists will be expected to participate in transdisciplinary efforts.

In addition, technological advances have facilitated an increase in transdisciplinary efforts. These innovations present opportunities to collaborate through the Internet via e-mail, web meetings, and data sharing. According to d'Andrea (2009), "Research is asked to be more effective, fast, accountable, trans-disciplinary, result-oriented, policy-driven and able to generate benefits for people and firms in the short and middle run".

Transdisciplinary research offers the potential for a variety of scientific rewards. In addition to the prospect of better research outcomes, transdisciplinary efforts offer the following: potential societal benefits from increased outcomes (Pohl, 2011), positive impact on participants disciplines and students (Harris & Lyons, 2013), increased publication rates (Porter et al. 2012), greater visibility in the scientific community (Goring, 2014), and the creation of professional relationships through networking (Katz & Martin, 1997; Goring, 2014).

### **The potential challenges of transdisciplinary research.**

While TDR approaches have great promise, tensions have been identified between the benefits of working across disciplinary boundaries to understand complex problems and the potential costs of such collaborations (Cummings & Kiesler, 2005). Once a transdisciplinary project has been developed, there are numerous potential challenges that should be



considered. Communication and language barriers are often cited as challenges to effective transdisciplinary work (Stock & Burton, 2011). In addition, “professional cultures” (Harris & Lyons, 2013) and cognitive cultural differences (Klein, 1996) exist within disciplines and create cohesion among group members that challenge collaboration across disciplines. On the other hand, too much similarity among scientists is detrimental as well and may stifle creativity and lead to “group think” (Rhoten, 2003). One key is to find the appropriate balance between solidarity and diversity (Stokols, 2005). Differing methodology among disciplines is another challenge (Harris & Lyons, 2013). To overcome such barriers, scientists must communicate and identify research goals and merge their respective methodologies to develop new strategies and techniques towards problem solving. Other cited challenges include: competition for funds (Roux, 2010), difficulty in reproducing research (Brandt et al. 2013), differing geographical locations of participants (Stokols, 2008; Cummings & Kiesler, 2005), and conflicting goals among team members (Bruneel, 2010).

### **Paper overview.**

The potential for improved outcomes using TDR versus traditional science methods presents opportunities for studying effective TDR development. Effective TDR projects, which include both the challenges and benefits of integrated science will likely produce better outcomes and serve as a framework for other similarly sized projects. To that end, research questions must move TDR science forward and provide relevant data for on-going, effective TDR development.

This paper explores a large transdisciplinary research project from a perspective that has been lacking in transdisciplinary research to date: participants’ attitudes and behaviors towards transdisciplinary research over time. This longitudinal panel study analyzed survey

data from the Climate and Corn-based Cropping Systems Coordinated Agricultural Project, or CSCAP. Through the analysis of survey data, the following research questions were addressed:

(1) Do project participants' attitudes and behaviors towards the transdisciplinary process change over time?

(2) Do changes in project participants' perspectives toward transdisciplinary research vary by role?

### **Research on Transdisciplinary Science**

#### **Evaluation of transdisciplinary projects.**

Evaluative studies for transdisciplinary research are necessary to demonstrate their effectiveness for ongoing financial and researcher support (Stokols, 2003). However, there are barriers to effective evaluation that are described in an article by Stokols et al. (2003). For instance, the hybrid nature of the research team creates complications for a standard and consistent evaluation process. Moreover, the evaluators of the integrative research endeavors are often non-neutral parties. They are either involved in the project itself, or have a stake in the results. An additional barrier is determining the appropriate time frame to evaluate whether outcomes have been met. Due to the nature of the complex problems that transdisciplinary teams are confronted with, it can sometimes take years for results to be realized.

With the complexity of the issues in mind, most studies focus on the outcomes in the latter stages of the project. However, a study at the National Cancer Institute evaluated the

collaborative-readiness of transdisciplinary projects. It explored characteristics of the Transdisciplinary Research Energetics and Cancer (TREC) initiative to assess the readiness of participants at the outset of the project (Hall et al. 2008). The authors of the study uncovered several factors that they identified as collaboration-readiness factors that influence teamwork in the initial stages of transdisciplinary projects. The antecedent factors can be categorized into three groups: contextual-environmental, which addresses the infrastructure considerations such as institutional supports/barriers environmental proximity, and electronic connectivity; intrapersonal characteristics which address research orientation and leadership qualities; and interpersonal factors which address group size, the variety of disciplines represented, and the researcher's histories in previous transdisciplinary projects. The authors argue that evaluation should occur throughout the project (Stokols et al. 2003), however, getting the project started in a positive direction by addressing antecedent factors (Hall et al. 2008) is an important aspect of transdisciplinary research. Readiness levels can be reinforced through increasing antecedent conditions, but should remain flexible enough to account for all the variations in project integration (Klein, 2008).

In addition to antecedent conditions, evaluating large projects involves an assessment at multiple levels. A transdisciplinary research literature review done by Klein (2008) revealed seven generic principles for transdisciplinary evaluation: 1) variability of goals, 2) variability of criteria and indicators, 3) leveraging of integration, 4) interaction of social and cognitive factors in collaboration, 5) management, leadership, and coaching, 6) iteration in a comprehensive and transparent system, and 7) effectiveness and impact.

Principle one, the variability of goals, is unavoidable in the context of transdisciplinary research given its merging of disciplines. Goals and objectives should be

decided on as a team and evaluated as such. The authors of the study found that the variability of goals also drives the second principle: variability of criteria and indicators. Principle three, evaluating the quality of the transdisciplinary project has traditionally been measured through outputs such as patents, publications, citations and peer approval in the scientific community. The fourth principle, leveraging of integration, addresses the idea of evaluating the quality of the process. In other words, evaluating the integration process itself. Principle four addresses the intersection between the intellectual and social factors of integration. The authors found that intellectual integration is influenced socially through shared learning activities, and mutual knowledge arises from this integration. Principle five addresses the evaluation of management and coaching. This principle calls for the evaluation of leadership, organizational structure, networking, and communication. Principle six addresses the importance of iteration to provide input opportunities, and transparency. This feedback opportunity was found to be an essential element. Finally, principle seven addresses the evaluation of effectiveness and impact. If evaluators look solely to this principle to evaluate transdisciplinary projects, there is valuable information missing that can improve on-going projects and current projects.

CSCAP project evaluators, with guidance from project leadership, determined that the evaluation objectives encompassed principles three through six by evaluating several key collaboration scales and one scientific integration scale as identified by the TTURC survey (Mâsse, 2008): transdisciplinary attitudes, satisfaction with collaboration, impact of collaboration, and trust and respect. Transdisciplinary behavior, an element of principle four, is also evaluated through the assessment of collaborative activities (Hall et al. 2008).

In addition, this paper attempts to analyze a transdisciplinary project from a unique perspective. Much of the research on transdisciplinary science thus far has been from the outside looking in. Evaluating transdisciplinary science and its place in future research requires the analysis of outcomes. Typically, evaluation is a third party endeavor. What is currently missing is the perspective of research participants involved in the project (Tress et al. 2005). Appraising the views and attitudes of those working within a transdisciplinary project is an important evaluative tool, as the experience of participants can ultimately affect outcomes. Participants can provide insight into understanding why they involve themselves in this challenging process while identifying barriers and incentives for doing so. This participant knowledge can direct project leaders in adapting resources or outcomes based on these critical insights.

Some observers of team science are concerned with the difficulty in proving its effectiveness. Benefits from project outcomes are sometimes not evident for years or decades into the future (Stokols, 2008). This delay in achieving project outcomes is difficult for participants who wish to experience the satisfaction of moving science forward, and for funders who expect to receive evidence that their funding choices are appropriate and successful. Opportunities for participants to provide feedback throughout the project gives leadership an awareness of project progress on an on-going basis, enabling them to highlight positive satisfaction areas, and identifying those that may need more attention.

### **Conceptual background and framework.**

The conceptual background for this study was largely based on experiences reported by the Transdisciplinary Tobacco Use Research Centers (TTURC) and Transdisciplinary Research on Energetics and Cancer (TREC) initiatives, two major NIH-funded

transdisciplinary research projects. These pioneering initiatives were instrumental in developing a framework for the evaluation of TDR projects. Prior quantitative research had largely focused on evaluating outcomes of TDR and very few studies evaluated the perspectives of the participants who work in these complex networks of scientists and stakeholders.

The CSCAP evaluation survey focused on several dimensions that TTURC and TREC research found to be critical determinants of effective TDR. The CSCAP project evaluation team employed an adaptation of the conceptual framework developed by Mâsse et al. (2008) to guide examination of change over time in project participants' perspectives and experiences with TDR. Figure 1 shows the relationships between a number of constructs that are conceptualized as predictors of project outcomes over time.

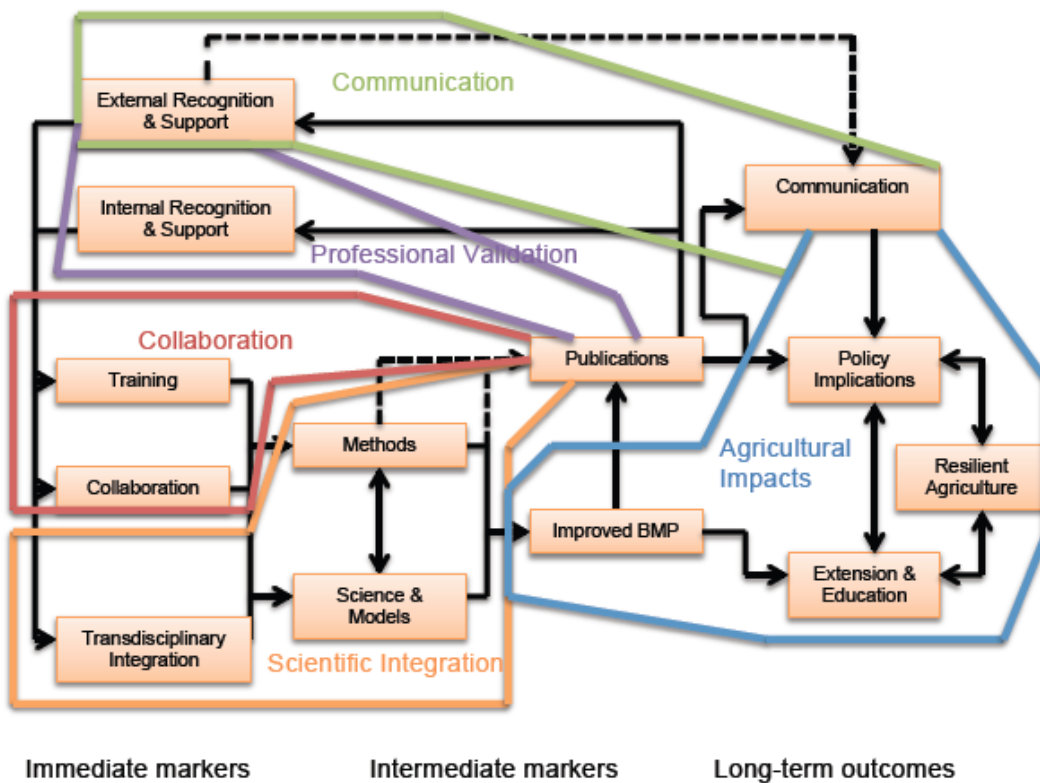


Figure 1: CSCAP Conceptual Model (Adapted from Mâsse 2008)

The CSCAP evaluation examined data for two of these constructs that are indicators for the immediate and intermediate timeframe: collaboration and scientific integration. For the collaboration node, the evaluators drew on concepts explicated by Hall et al. (2008). For Hall et al. (2008), “collaborative readiness,” or factors that enable or limit effective teamwork, are critical building blocks of long-term project success. Specifically, the factors are: 1) contextual-environmental conditions (e.g., institutional resources, technical infrastructure); 2) intrapersonal characteristics (e.g., research orientation, leadership quality); and 3) interpersonal factors (e.g., history of PI collaboration, team size, variability of team disciplines). The latter two are human qualities that are more likely to be influenced over time by the process of TDR (Hall et al. 2008).

Transdisciplinary integration is a foundational node in the scientific integration sector of Figure 1. Because integration of scientists from different disciplines is a necessary condition for the success of transdisciplinary projects, Mâsse et al. (2008) emphasized the importance of understanding project participants’ attitudes toward transdisciplinary research. This is an important measure based on the assumption that any positive changes in transdisciplinary behavior will be preceded by positive shifts in attitudes towards transdisciplinary efforts.

The CSCAP evaluators drew primarily on a combination of both the TTURC and TREC survey items to develop a set of measures that would facilitate evaluation of project participants’ perspectives on collaboration and transdisciplinary integration over time. Under the collaboration category, measures of collaborative behaviors, satisfaction with collaboration, impacts of collaboration, and trust and respect were adapted from Hall et al.

(2008). Measures of attitudes toward transdisciplinary integration were developed primarily from Mâsse et al. (2008).

### **Research objectives.**

Numerous studies have examined characteristics that intersect to build the foundation of effective TDR. A number of these studies have been case studies that have employed mostly qualitative methods to identify and measure effective project characteristics and post-project outcomes. Project success has been linked to the following foundational components: interpersonal skills such as communication and social engagement (Cheruvilil, 2014; Katz & Martin, 1999; Kessel, 2008; Stokols, 2003), diversity of team members (Cheruvilil, 2014; Roux, 2010; Hampton & Parker, 2011), integration of disciplines (Wickson, 2006; Kessel, 2008; Hampton & Parker, 2011), commitment to common goals (Cheruvilil, 2014; Kessel, 2008), transdisciplinary ethic (Stokols, 1999) and trust (Kessel, 2008; Hampton & Parker, 2011; Harris & Lyon, 2013).

Few studies have systematically assessed the experiences of participants over time. An important exception is Stokols et al. (2005). Stokols et al. (2005) published a longitudinal study that analyzed collaborative processes and outcomes at multiple TTURC centers from 1999 to 2004. Our study couples a longitudinal analysis with an examination of processes and outcomes with geographically dispersed teams. To our knowledge, no research has examined how project participants' perspectives might change over the course of project participation in such a diffuse team environment.

Participant experiences are important when considering the long-term viability of TDR projects. Theoretically, if participants have an overall positive experience, they may be more committed to current TDR projects and more willing to engage in future projects. In



addition, those having a positive experience may be more inclined to engage in mentoring relationships with students, or be actively involved at the leadership level. This analysis hopes to contribute to the science of TDR by filling this gap in research. Given the interpersonal characteristics of TDR and the typical length of these projects, it is important to understand participants' attitudes and beliefs towards such projects, and to help understand any changes in attitude and behavior that may occur over time. This research, through analysis of participant survey data, provided insights of those who are actively involved in the transdisciplinary process. The survey provided data to answer the following research questions: 1) Do project participants' attitudes and behaviors towards the transdisciplinary process change over time? 2) Do these changes vary by participant role? We expect that attitudes about the process of collaboration will change as relationships within the project develop, data are collected and analyzed, and project objectives are met. A better understanding of how participants' perspectives change over time, and the magnitude and direction of changes could inform future project management strategies.

### **Materials and Methods**

#### **Climate and Corn-based Cropping Systems Agricultural Project (CSCAP).**

The CSCAP was a five-year, \$20 million project funded through a partnership between USDA and the National Institute for Food and Agriculture (NIFA) to research strategies for increasing the resilience of corn-based cropping systems to adapt to changes in climate. The four overarching goals of the project were: 1) retain and enhance soil organic matter and nutrient and carbon stocks 2) reduce off-field nitrogen losses that contribute to greenhouse gas emissions and water pollution 3) better withstand droughts and floods 4) ensure productivity under different climatic conditions.

The CSCAP project spanned nine midwestern states, 11 land grant universities, and 35 field sites. It integrated scientists across many different disciplines, and a variety of representatives of key stakeholder groups (e.g., agricultural industry, farmers, and NGO's), all who partnered in this complex collaboration. It was a strong example of transdisciplinary, issues-driven science as it related to the complex interactions of climate variability and sustainability (figure 2). In addition, it involved multiple non-academic entities, which is a critical element of transdisciplinary research.

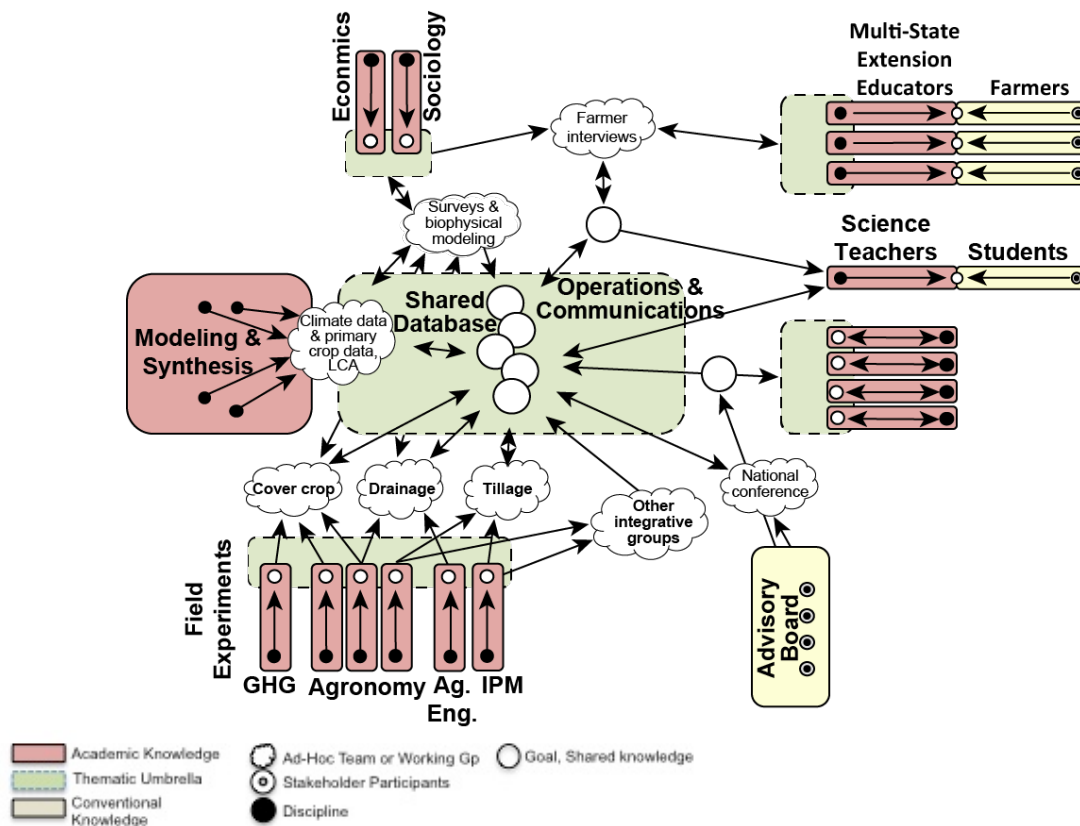


Figure 2. CSCAP Project: Transdisciplinary science mode

The ultimate objective of this TDR project was to build a high-functioning, regionally coordinated network of science-based research, extension, and education that informed decision and policymaking regarding the climate change and agriculture in the Corn Belt region. (CSCAP 4 year report, 2014).

**CSCAP participants.**

The CSCAP project participants and collaborators, based on their skill-set, represented various objectives within the project. Each team focused on one of two areas, research or support. The research-oriented teams involved the majority of project participants and included the following: the Field/Research team tasked with developing methods for monitoring carbon, nitrogen and water footprints at field sites over the Midwest; the Analysis and Predictive Modeling team which worked to integrate climate and economic data into a shared database for life-cycle analysis and modeling; the social and Economic Research team which elicited farmers' beliefs and concerns regarding climate change, their attitudes regarding mitigation, and decision-making supports; the Extension team promoted knowledge exchanges between farmers and Extension team members; the Education team was tasked with developing educational materials and opportunities to students at all levels from high school to graduate school.

Principal Investigators. The project had about 50 PIs, who were leaders of the research effort and served as mentors to the graduate students. The PIs were instrumental in the development of the grant and were scientific leaders on project teams. Each team combined scientists from various disciplines, and non-academic participants from within and across the eleven institutions. As part of the leadership team, PIs were involved in the project from the beginning and were expected to provide leadership for the duration of the project.

Professional & Technical Staff. The role of Professional & Technical Staff was largely scientific. These researchers were generally hired by PIs to assist with the daily scientific work of the project. The 27 researchers in this group were all members of a project team.

Graduate Students. The role of Graduate Student was one of scientist in training and included approximately 47 students at the Masters and Doctoral level, spanning numerous disciplines. Four years into the five-year project, graduate students were involved in the publication of 19 articles in which they authored or co-authored. As students graduated, other students were brought into the project to help advance the research directives and become discipline-based scientists who could collaborate across disciplines to solve complex issues. As of 2014, a total of 83 graduate students contributed to the project and gained valuable experience as next generation scientists. Graduate students in this project were acutely aware of their potential contribution in the future of TDR. In an article written by CSCAP students, they reflected on their unique role by stating, “We are on the frontier of a transformative era of new science, based on a changing scientific landscape that will demand greater transdisciplinary efforts and team science... Therefore students are part of a natural experiment—a practical exercise in new research territory—in how the next generation of scientists will be trained and maneuver in a transdisciplinary environment” (Basche et al. 2014).

Advisory Board. The 19 member advisory board existed to serve as an external voice in project development and implementation. The coordinated effort of the CSCAP project benefited from the advisory board members guidance based on their wide range of expertise from farm production, scientific research, and executive management. In addition, they helped network the numerous stakeholders involved, including representatives from the agricultural industry (e.g., Monsanto, GNP Company), research centers (e.g., University of Kansas: Biodiversity Institute, National Laboratory for Agriculture and the Environment, North Central Regional Association of State Agricultural Experiment Stations), agricultural

crop boards (e.g., United Soybean Board), federal and state interests (e.g., National Resource Conservation Services, Colorado Water Institute), non-profits (e.g., National Association of Conservation Districts, National Academy of Sciences), and producers representing several Midwestern states. This external advisory board met regularly with the executive team via a monthly teleconference, and networked with all project participants at the annual meeting. This large and complex integration of third party representatives provided the necessary component to move this research effort from an interdisciplinary project to a transdisciplinary one.

Extension Educators. The extension educators played a unique role. By nature, the work of extension personnel is interdisciplinary. However, extension educators generally have a professional role, rather than that of a researcher. There were 18 extension educators actively involved in this project. They, through the nature of their work, translated the science and provided critical links between researchers and the stakeholders.

One of the main directives of the extension team was that of outreach. Through focus groups, one-on-one discussions, field days, and publications, they promoted an exchange of information and knowledge between project participants and by the end of the fourth year, had reached over 7000 farmers, crop consultants and other extension personnel. This project, through strategic capacity building, established a network of farmers and other agriculture professional who evaluated the crop management practices being tested at field sites.

Extension educators interviewed one hundred fifty-nine farmers to help the project team understand farmer perspectives on climate changes and possible impacts on agriculture.

Additionally, extension team members capitalized on their experience with introducing

strategies to promote farmer learning and implementation of appropriate management approaches.

In addition to research-oriented teams, the Staff/Operations team was tasked with providing operational support to all project members.

Effective communication is considered an important aspect of transdisciplinary efforts and face-to-face meetings are integral to building and maintaining cohesiveness and trust among team members (Eigenbrode et al. 2014; Hampton & Parker, 2011; Stokols, 2003). To that end, regular communication was an expectation in this project. Due to geographic barriers, communication was achieved through a variety of methods. Face to face meetings occurred annually at the project conference, and more informally at each academic institution when possible.

When face-to-face collaboration was not practical, team phone calls using Adobe Connect technology, allowed participants to interact and share project documents. These meetings were scheduled monthly for the entire team, leadership team, and research team. Webinars were offered annually to help train the next generation of scientists, as well as a graduate student workshop scheduled near the end of the project timeline to provide direction towards their next steps as students and professionals.

Communication via email and shared material on the CSCAP website ([sustainablecorn.org](http://sustainablecorn.org)) provided another avenue for team members outside of academia to be actively involved and access research and other pertinent information in a timely manner. The website also contained resources such as fact sheets and research summaries to communicate the methods and objectives of project teams.

**Survey sample.**

Data for this study were from a 2011 and 2013 (pre-assessment and mid-assessment) evaluation survey developed to measure project participants attitudes, beliefs and actions related to climate change and the CSCAP project itself. In addition, it was the intent of the survey to provide a longitudinal study to measure participants' beliefs and attitudes in collaborative scientific research and track any changes over time.

In November of 2011, soon after the project was initiated, the CSCAP baseline survey (pre-assessment) was administered via email to 140 project participants. Out of the 140 eligible participants, 121 completed the survey. Project participants who joined the project after the initial distribution of the survey were also asked to complete it and their scores were added to the baseline data. Twenty-three out of 29 eligible participants were added to this baseline for a total of 143 respondents.

In July of 2013, the CSCAP mid-term assessment was administered via email to all project participants (n= 157). Of the 157 eligible participants, 84 completed the survey. In order to evaluate changes in attitudes, beliefs, and actions over time, only those individuals who participated in both the pre and mid-assessment were used in the final sample. The sample size for those participating in both surveys (pre and mid) was 75. Seven of those 75 had selected "other" as their project role. Because we employ project role as a comparison variable, and we could not determine the meaning of "other," these observations were dropped, resulting in a final sample of 68 project participants who took both surveys. After accounting for participants completing both surveys and dropping the "other" role subgroup, the percentage of participants surveyed was 43%.

The average age of the respondent was 42 years, and the majority were male (73%). Sixty-five different disciplines were listed by respondents in an open-ended question with the average number of disciplines per respondent being 1.6. The top three disciplines reported were Agronomy (30.3%), Soil Science (17.6%), and Plant Pathology (9.2%).

To test for non-respondent bias, we compared non-respondents scale means to respondents scale means. Non-respondents were identified as individuals that participated in either the pre- or mid-assessment survey, but not both. We conducted independent samples t-tests to compare means for all of our variables of interest. No statistically significant differences were identified between respondents and non-respondents.

### **Measures.**

Five question sets were employed to measure facets of (1) general attitudes toward transdisciplinary integration and (2) the four dimensions of collaboration. The first question set measured attitudes toward transdisciplinary integration. The four collaboration categories included measures of collaborative behaviors, satisfaction with collaboration, evaluation of the impacts of collaboration, and trust and respect among project participants. All five question sets were administered in both years of the survey.

Four of the five question sets noted above employed a 5-point scale ranging from “strongly disagree” (1) to “strongly agree” (5), with 3 being “neutral.” A sixth response category, “don’t know,” was also included (6). Initial analysis showed that no respondent had selected the “strongly disagree” category for any of the items, and very few respondents (~1-2%) had selected the “disagree category”. There were, however, a substantial number of observations in the “don’t know” categories for most variables. Because we did not want to lose any observations due to the small sample size, the “don’t know” categories were



combined with the “disagree” and “neutral” categories to form a “not agree” category for each item. This resulted in a three-point scale from not agree (0), agree (1) and strongly agree (2).

***Transdisciplinary attitudes.*** Attitudes towards transdisciplinary integration were measured by evaluating the extent to which participants’ agreed with basic characteristics of transdisciplinary science. The scale included questions related to the value of TDR and optimism towards TDR outcomes. Transdisciplinary science was defined for participants’ by utilizing Rosenfield’s (1992) conceptualization. All 11 questions were drawn from the TTURC survey (Mâsse et al. 2008), with minor modifications to align with CSCAP language. A 5-point scale was utilized, ranging from strongly disagree (1) to strongly agree (5), with 3 being “neutral.” A sixth response category, “don’t know,” was also included (6). The full text survey items are presented in table 1.

Table 1. Transdisciplinary attitude: individual survey items

I describe myself as someone who strongly values transdisciplinary collaboration
Transdisciplinary research in the CSCAP stimulates me to change my thinking
I have changed the way I pursue research ideas because of my involvement in the transdisciplinary CSCAP
Transdisciplinary research has improved how I conduct research
CSCAP team members are open-minded about considering research perspectives from disciplines other than their own
I am optimistic that the transdisciplinary research of the CSCAP will lead to valuable outcomes that would not occur without this kind of collaboration
Addressing issues through a transdisciplinary team approach results in better research, education, and outreach
Because of my involvement in transdisciplinary research, I have an increased understanding of what my own discipline brings to the collaboration
Generally speaking, I believe that the benefits of transdisciplinary scientific research outweigh the inconveniences and costs of such work
I am comfortable working in a transdisciplinary environment
Overall, I am pleased with the effort I have made to engage in Transdisciplinary research for the CSCAP

***Collaborative behaviors.*** The collaborative behaviors items measured the frequency with which CSCAP team members participated in transdisciplinary behaviors outside of their primary discipline. Adapted primarily from the TREC “collaborative activities” scale (Hall et al. 2008) the survey asked participants to indicate how frequently they participated in a series of eight items measuring frequency of transdisciplinary behaviors on a five-point scale (“Never”, “Once or twice a year”, “Quarterly”, “Monthly”, or “Weekly”). Six of the items were drawn directly from the TREC study. Two additional items were created by CSCAP personnel to measure grant proposal activity, which is believed to be an important indicator of transdisciplinary collaboration in the realm of agricultural research. The behaviors selected for evaluation were established to represent actions beyond those of traditional disciplinary scientists such as reading journals or publications outside their reported disciplines, and establishing links with colleagues from other disciplines. The full text survey items are presented in table 2.

Table 2. Collaborative behaviors: individual survey items

Pre: Prior to January 2011 (the start of the CSCAP), how frequently did you do each of the following?
Mid: During your participation in the CSCAP project, how frequently have you done each of the following?
Read journals or publication outside your primary, secondary, or third disciplines
Attended meetings or conferences outside your primary, secondary, or third disciplines
Participated in working groups or committees with the intent to learn from researchers in other disciplines
Submitted grant proposals, <u>other than the CSCAP</u> , in partnership with colleagues or others outside your primary, secondary, or third disciplines
Received grant funding rewards, <u>other than the CSCAP</u> , in partnership with colleagues or others outside your primary, secondary, or third disciplines
Obtained new insights into your own work through discussion with colleagues from other disciplines
Modified your own work or research agenda as a result of discussions with colleagues from other disciplines
Established links with colleagues from other disciplines that led to or may lead to future collaborative work

***Satisfaction with collaboration.*** Six items measured satisfaction with collaboration and team cohesiveness. Derived from the collaboration dimension of the TTURC survey (Mâsse et al. 2008), the survey asked CSCAP participants the extent to which they agreed with statements about the CSCAP team on a 5-point scale ranging from strongly disagree (1) to strongly agree (5), with 3 being “neutral.” A sixth response category, “don’t know,” was also included (6). Five items were drawn directly from the TTURC study to examine team cohesiveness. Example questions included: acceptance of new ideas, and organization and structure of the team. One additional item was added by the CSCAP Program Coordinator to evaluate potential frustrations with team members. The decision was made to word the question positively to avoid reliability problems that had been identified for negatively worded questions in the TTURC survey (Mâsse et al 2008). The full text survey items are presented in table 3.

Table 3. Satisfaction with collaboration: individual survey items

The CSCAP team is accepting of new ideas
There is good communication among CSCAP team members
The CSCAP team is able to capitalize on the strengths of different researchers
The organization and structure of the CSCAP team is working well
The CSCAP team is able to accommodate the different working styles of team members
CSCAP team members are responsive to requests for information or action from other CSCAP team members

***Impact of collaboration.*** Another question set focused on the impacts of collaboration. Six items measured the CSCAP participants’ perceptions regarding the overall outcomes of the CSCAP project including productivity and quality. All six survey questions were drawn directly from the collaboration section of the TTURC survey (Mâsse et al. 2008) and adapted to align with productivity language specific to the CSCAP project. The survey asked CSCAP participants the extent to which they agreed with statements about the CSCAP outcomes on a 5-point scale ranging from strongly disagree (1) to strongly agree (5), with 3

being “neutral.” A sixth response category, “don’t know,” was also included (6). Questions ranged from assessing the overall productivity of the team to individual research quality. The full text survey items are also presented in table 4.

Table 4. Impact of collaboration: individual survey items

The CSCAP group meetings are productive
Overall CSCAP productivity (i.e., data, methodologies, modules, publications, and other products) is high
Overall quality of CSCAP data, methodologies, modules, publications, and other products is high
In general, the CSCAP has improved my research productivity (i.e., data, methodologies, modules, publications, and other products)
In general, the CSCAP has improved the quality of my research
Time spent of the CSCAP is well worth the effort in terms of returns I am receiving

***Trust and respect.*** Six items measured the extent to which CSCAP participants trusted and respected other team members. It evaluated participants’ comfort level by assessing the degree to which they were willing to take risks by voicing their opinions and accepting constructive criticism without concern about negative consequences. Four survey questions were drawn directly from the collaboration section of the TTURC survey (Mâsse et al. 2008). Two additional items were added by CSCAP personnel to assess possible concerns about appropriation of ideas and comfort in sharing thoughts and ideas with an integrated audience. A 5-point scale was employed, ranging from strongly disagree (1) to strongly agree (5), with 3 being “neutral.” A sixth response category, “don’t know,” was also included (6). The full text survey items are also presented in table 5.

Table 5: Trust and respect: individual survey items

I am comfortable showing limits or gaps in my knowledge to CSCAP team members
In general, I feel I can trust the CSCAP team
In general, I find the CSCAP team members are open to constructive criticism
In general, I respect the CSCAP team members
I trust other CSCAP team members will not exploit or otherwise misappropriate ideas or information I share
I feel comfortable voicing my thoughts, knowledge, and opinions during CSCAP meetings and conference calls

***Summated scales.*** Summated scale measures were created for all conceptual areas. The transdisciplinary behavior question set, measured behavior on a five-point frequency scale ranging from never (1) to weekly (5), and thus was not converted into a 3-point scale. Summated rating scales are often considered to be better for attitude measurement than multiple single-item scales because attitudinal constructs are complex and multidimensional (DeVellis 2003; McIver and Carmines 1981; Spector 1992). Use of summated scales that combine multiple single-item scales to measure attitudinal constructs can improve both reliability and precision of measurement, and address collinearity between closely related items that measure latent constructs (Field 2013). The four scales comprised of the recoded agreement scales were constructed by summing the 3-point (not agree, agree, strongly agree) items then dividing the sum by the number of items (DeVellis, 2003; McIver, 1981).

**Participant roles.**

The roles variable was measured by offering seven different roles and asking the participant to choose the role that best fit their responsibilities. The roles offered to respondents included: “PI”; “Professional & technical staff”; “Graduate Student”; “Advisory Board” and “Extension Educator”. This variable relates directly to our second research question, do changes in participants’ perspectives toward transdisciplinary research vary by their role in the project? Roles may impact measures due to participants varying degrees of experience in TDR, and general knowledge of the scientific process. Therefore, it is hypothesized that different roles, and possibly different levels of academic status, may impact levels of trust and collaboration. This question was asked for the pre-assessment and not the mid-assessment. It was assumed that roles would not change during the time period

between assessments. Different roles of participants were analyzed and compared to their attitudes and behaviors towards transdisciplinary research. The summary of roles and percentages are listed in table 6.

Table 6: Percentage distribution of project participants by role

Project participant role	Percentage reported
PI (n=25)	36.8%
Professional & technical staff (n=10)	14.7%
Graduate Student (n=21)	30.9%
Advisory Board (n=4)	5.9%
Extension educator (n=8)	11.8%

### **Analysis.**

*Analytical approach.* The longitudinal panel design of the survey allowed us to evaluate changes over time by comparing pre-assessment data to mid-assessment data. Paired-samples t-tests were employed to assess whether the means from the pre and the mid-assessment were statistically different. The paired-samples t-test compares two means that come from the same individuals (Field, 2013). Because we utilized only those participants who completed both the pre- and the mid-assessment, it resulted in a smaller sample size (n=68). Due to the small sample size, we report all results that were at the  $p < .10$  level. The analysis was conducted in two stages. First, a paired t-test was conducted for the full sample. Then, to examine potential changes in subgroups, the file was split by role and a second paired t-test was conducted to evaluate changes within role groups.

### **Results**

The summated scale results and Cronbach's alpha reliability coefficients are found in Table 7. The Cronbach's alpha is a measure of reliability for psychometric testing. Our Cronbach's alpha results were all greater than .792, which indicates good reliability. All

scales showed a significant mean difference increase, except that of TD behavior, which showed a decrease (not significant).

Table 7. Results for CSCAP evaluation measures

	Pre-assessment			Mid-assessment			Paired t-test mean difference
	Mean	SD	$\alpha$	Mean	SD	$\alpha$	
Transdisciplinary attitudes	9.67	5.03	.878	11.27	4.87	.877	1.6*
Collaborative behavior	19.13	5.40	.814	18.48	4.67	.792	-.65
Satisfaction with collaboration	4.10	3.51	.883	5.81	3.18	.846	1.71**
Impact of collaboration	3.10	3.07	.839	4.80	3.28	.893	1.7***
Trust and respect	5.34	3.37	.876	7.16	2.86	.837	1.82**

$p < .10^a$ ; \* $p < .05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$

### **Transdisciplinary attitude.**

The overall mean scores for the transdisciplinary attitude scale on the pre- and mid-assessment were 9.8 and 11.3, respectively, out of a maximum score of 22. This difference, 1.5, was significant at the ( $p < .05$ ) level. Analysis by role identified statistically significant differences for the PI, graduate student, and advisory board subgroups (Figure 3). PI respondents reported an increase from 8.6 to 12.2 ( $p < .01$ ). Advisory board respondents showed a positive increase from 6.5 to 9.8 ( $p < .05$ ). The only role that reported a decrease in attitude scores from pre-assessment to mid-assessment was the graduate student subgroup, which decreased from 12.8 to 11.7 ( $p < .10$ ).

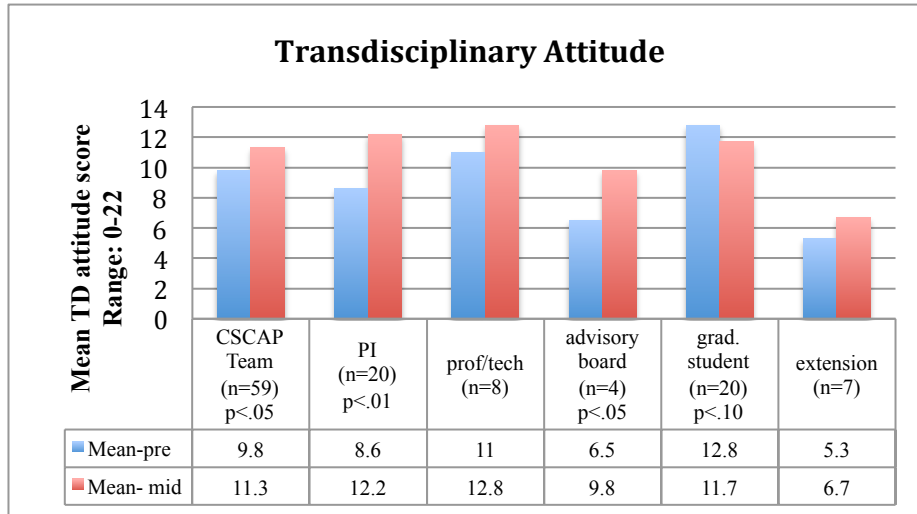


Figure 3. Transdisciplinary attitudes: Change over time (2011, 2013) for CSCAP team and role subgroups

### **Collaborative behaviors.**

The overall mean scores for the collaborative behaviors scale for the pre- and mid-assessment were 19.3 and 18.5, respectively, out of a maximum score of 40. However, this result was not statistically significant ( $p=.180$ ). The only role that was found to have a statistically significant change was that of the advisory board as shown in figure 4. Advisory board respondents reported a pre-assessment mean of 25.0 and a mid-assessment score of 19.3 ( $p<.01$ ).



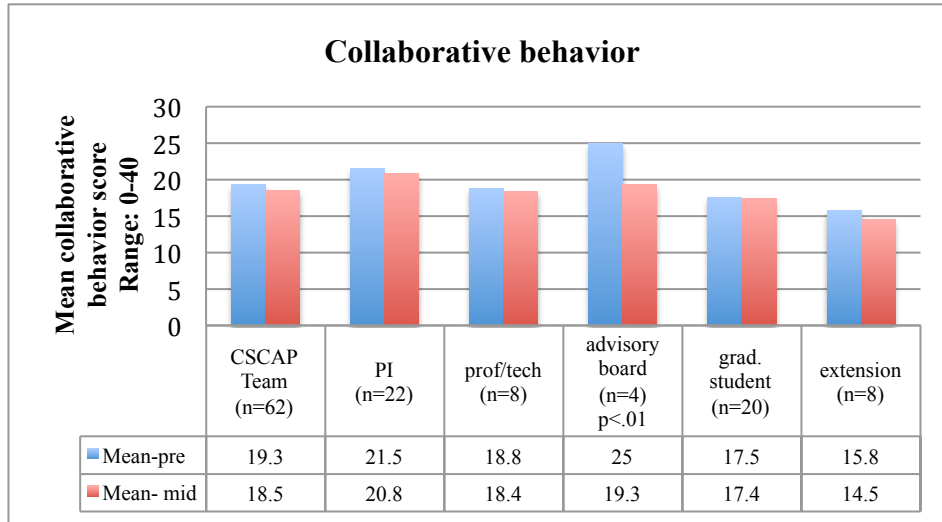


Figure 4. Collaborative behavior: Change over time (2011, 2013) for CSCAP team and role subgroups

### **Satisfaction with collaboration.**

The overall CSCAP mean scores for the satisfaction with collaboration scale on the pre- and mid-assessment were 4.2 and 5.8, respectively, out of a maximum score of 12 (Figure 5). This difference, 1.6, was statistically significant ( $p < .001$ ). Analysis by role revealed statistically significant changes for the PI, advisory board, and extension subgroups. PI respondents reported an increase from 4.1 to 5.6 ( $p < .01$ ). Advisory board respondents reported a shift from 0.0 to 5.5 ( $p < .01$ ). Mean scores for the extension subgroup reported increased from 1.0 to 5.1 ( $p < .05$ ).

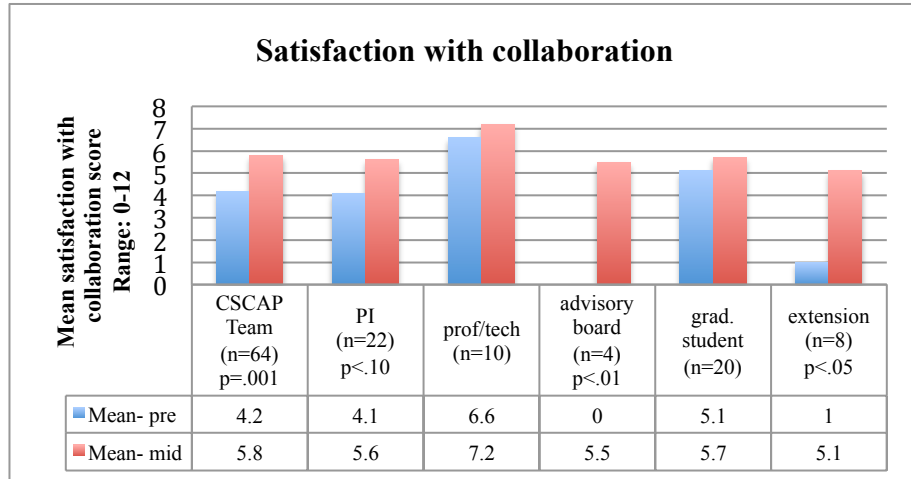


Figure 5. Satisfaction with collaboration: Change over time (2011, 2013) for CSCAP team and role subgroups

### Impact of collaboration.

The overall mean scores for the CSCAP team on the pre- and mid-assessment were 3.1 and 4.8, respectively, out of a maximum score of 12. This difference, 1.7, was significant at the ( $p<.001$ ) level. Analysis by role revealed statistically significant changes for the PI, professional/technical, advisory board, and extension subgroups (figure 6). PIs reported an increase from 2.9 to 5.1 ( $p=.001$ ). Professional/technical scores increased from 4.5 to 6.8 ( $p<.05$ ). Advisory board respondents reported an increase from 0.3 to 5.5 ( $p<.01$ ). Extension respondents also reported an increase from 0.4 to 2.9 ( $p<.10$ ).

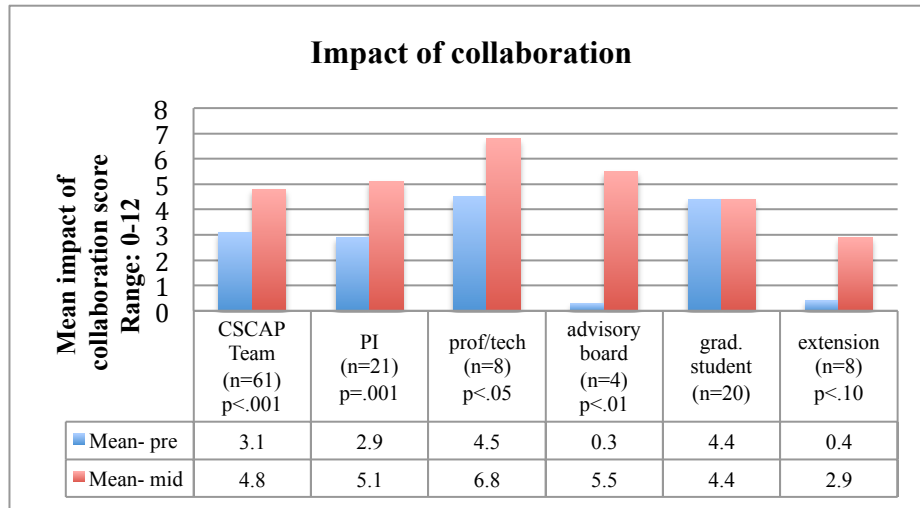


Figure 6. Impact of collaboration: Change over time (2011, 2013) for CSCAP team and role subgroups

### **Trust and respect.**

The overall mean scores for the trust and respect scale on the pre- and mid-assessment were 5.3 and 7.2, respectively, out of a maximum score of 12. This difference, 1.9, was significant at the ( $p<.001$ ) level. Analysis by role revealed statistically significant data changes for PI, advisory board, and extension subgroups (Figure 7). PI scores increased from 5.6 to 7.1 ( $p<.05$ ). Advisory board scores increased from 4.5 to 7.3 ( $p<.05$ ). Extension respondents also reported a positive change from 2.9 to 7.8 ( $p<.05$ ).

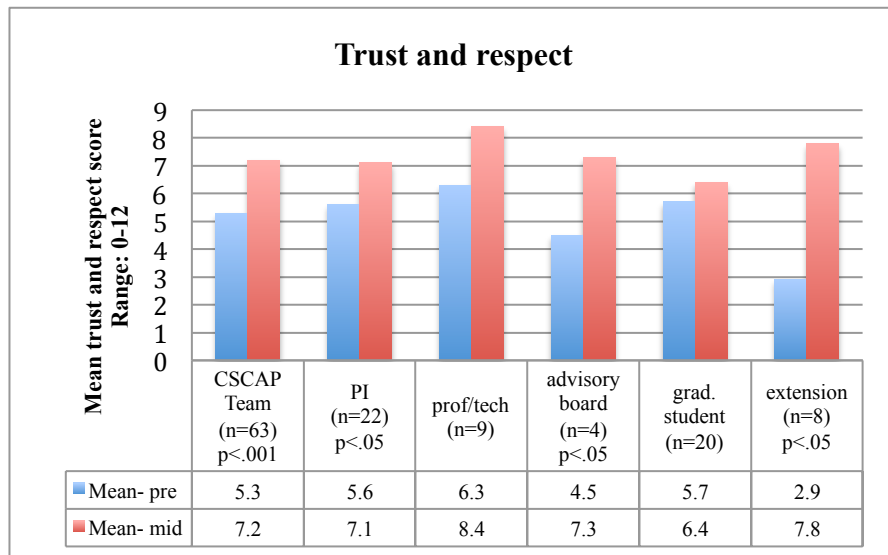


Figure 7. Trust and respect: Change over time (2011, 2013) for CSCAP team and role subgroups

## Discussion

### Transdisciplinary attitudes.

Significant changes in attitude from the pre- to mid-assessments were found for the both the overall CSCAP team and the PI, graduate student, and advisory board subgroups. The PI and advisory board member subgroups showed significant positive changes over time, suggesting that project participation might lead to improved attitudes toward TD research. Graduate students, on the other hand, showed a significant decline in attitudes toward TD research between the pre- and the mid-assessment. This negative shift might be explained by the graduate students' initial enthusiasm for the idea of collaborative science, and then a re-alignment once they have discovered the challenges associated with such complex work. It is possible that graduate students have had fewer opportunities to engage in TD projects prior to the CSCAP, and therefore may have had more positive attitudes than those team members who had participated in TD work in the past.

**Collaborative behaviors.**

One interesting finding was that collaborative behaviors did not change over time for most subgroups. The one exception occurred with the advisory board, which reported a significant negative change in TD behavior between the pre- and mid-assessment. This finding is congruent with the premise that behavior change occurs over a long period of time and is preceded by changes in attitude. It could also indicate a pre-existing tendency towards collaborative behaviors for a significant population of participants who engage in TDR.

**Satisfaction with collaboration.**

The satisfaction with collaboration results showed significant positive change for the overall team, the PIs, the advisory board, and extension. This positive shift suggested that time spent working on the project allowed team members to develop interpersonal relationships and team compatibility. An interesting follow up would be to explore why graduate students did not show a statistically significant positive change in the satisfaction with collaboration. One potential explanation is that graduate students feel less a part of the team due to their status as a “next generation scientist” which suggests a hierarchy in the team.

In addition, the CSCAP evaluation study revealed similar results when compared to the TREC study. Hall et al. (2008) found that the more positively a participant rates interpersonal relationships at the TD center, the more positive the overall assessment will be. Similarly, the CSCAP evaluation study revealed positive interpersonal ratings of the majority of subgroup participants, and an overall significant positive change as well.

**Impact of collaboration.**

The impact of collaboration analysis revealed a significant positive change for the overall team ratings between the pre-and mid-assessment. Additionally, there were significant positive changes for the following subgroups: PI, professional/tech, advisory board, and extension. These positive changes may be related to the nature of project outcomes, which are closely associated with the daily work of the PI, professional/technical, and extension position. Again, it is interesting to note that there is not a significant positive change at the graduate student level, once again reinforcing the idea that graduate students may to some extent feel less integrated into the research process.

**Trust and respect.**

Previous studies have highlighted the importance of establishing trust within these large collaborative efforts. This evaluation study examined trust and respect among CSCAP team members. The trust and respect analysis revealed a significant positive change from the pre- to mid-assessment for the overall team. This is not an unexpected finding given the assumption that trust builds over time, under the right conditions. Positive significant changes were also found in the PI, advisory board, and extension subgroups. The extension and advisory board subgroups showed the largest change in mean score. One possible explanation for this is their role outside of conventional research. Neither the advisory board members nor extension personnel are directly involved in the research process under traditional research design. However, under the transdisciplinary model, both subgroups are actively involved and have the opportunity to give input. This increased engagement may facilitate trust building where the opportunities were previously lacking.

This study suggests that there are significant changes in attitudes and perceptions towards transdisciplinary science over time and that these changes do vary by role. Understanding the nature of these changes could provide future TDR projects with a framework from which to develop and adapt long-term projects.

### **Conclusion**

Perhaps the greatest benefit of transdisciplinary science, and the one that led to the emergence of this integrative science, is the sharing of knowledge, skills, and ideas (Katz & Martin, 1997). As Katz & Martin (1997) explain it, "...collaboration is greater than the sum of its parts".

To increase understanding of effective collaborative science, the CSCAP project, massive and complex, provided a unique opportunity to examine change over time among the overall CSCAP team and by subgroup. This exploratory research study sought to identify areas of change. Is change happening, and where is it happening? Some results mirror those of other studies, while others offer directions for future research in the field of TDR. The CSCAP evaluation research contributes to TD science by providing a longitudinal data set to examine participants' attitudes and behaviors over time. The data were collected from 68 CSCAP project participants who completed both a pre- and mid-assessment survey. Differences between the pre- and mid-assessment scores were analyzed using a paired samples t-test to compare means. The results indicated that there were changes in responses over time, and that subgroup differences were also evident.

By utilizing the conceptual framework developed in the TREC and TTURC initiatives, the CSCAP survey was developed to assess attitudes, beliefs, and behaviors associated with climate change and transdisciplinary science. For the purposes of this study,

participants' perceptions regarding TD attitudes, collaborative behaviors, satisfaction with collaboration, impact of collaboration, and trust and respect, were analyzed.

Although the breadth of transdisciplinary research is growing rapidly, a gap for future research still remains. An important perspective that is often unnoticed is the role of the non-principal investigator (Stokols, 2003). Graduate students are a good example of this and can provide valuable insights into team development. An interesting finding in this research was the declining scores in transdisciplinary attitudes among graduate students from the pre-assessment to the mid-assessment. Graduate students are in a distinctly difficult position. The contrasting goals of establishing themselves in their respective fields (Stokols et al. 2008) and participating in the growing field of team science can seem at odds. The current academic culture values certain research outputs over others, such as primary-authored publications, which can be problematic for early-career researchers involved in collaborative research (Goring et al. 2014). Additionally, the training provided for transdisciplinary research for graduate students can often be inconsistent. For instance, graduate students may be involved in multiple or evolving projects over the course of their studies and those studies could occur at more than one institution by the time they graduate, and post-graduate studies are complete (Goring et al. 2014). In contrast, transdisciplinary attitudes of the PI and advisory board subgroups showed a significant positive change. What accounts for these differences? These two groups, especially that of the PI is likely to be working with colleagues of similar status, whereas graduate students, may find the power differential intimidating. Identifying what drives these attitudinal differences is an important area to explore. A follow up study to this one, using the same data, will attempt to identify key measures that may help predict attitudinal shifts by participants in TD research.



Due to the complexity of the problems that transdisciplinary teams are tasked to solve, many are multi-year endeavors. It is possible during the course of the project that collaborations, and levels of collaboration, will shift and change, either by design or naturally (Wright Morton et al. in process). Using the results of this study and others like it, researchers can provide key information that could assist project developers and leaders with data to make informed decisions on shifts and changes that may occur over the life of the project and be prepared to make necessary adjustments to help ensure the overall efficacy of project outcomes.

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## CHAPTER 3

DETERMINANTS OF PARTICIPANTS' PERCEPTIONS TOWARDS  
TRANSDISCIPLINARY SCIENCE OVER TIME

A paper to be submitted to *Futures*

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**Abstract**

Transdisciplinary research (TDR) has developed over the past few decades to become an increasingly relevant method for exploring today's most complex problems. It requires scientists to cross-disciplinary boundaries to collaborate, network, and ultimately produce outcomes, which address system based problems. Using a longitudinal panel study, we examined relationships within the context of a multi-institutional transdisciplinary midwestern agricultural project. Our survey data was collected from pre-assessment (2011) and mid-assessment (2013) evaluation surveys of project participants. A multiple regression analysis was employed to assess the relationship between transdisciplinary (TD) attitude and other identified measures. The key variables were role, gender, transdisciplinary behaviors, satisfaction with collaboration, perceived impacts of collaboration, and trust and respect. These variables were chosen for our regression model because we expected to find that they



could have an impact on project participants' attitudes towards TDR. The analysis examined the following research question: What factors are associated with changes in attitudes toward transdisciplinary research over time? Results indicate that there is a positive relationship between TD attitudes and the participants' perception of trust and respect within the project. Comparing TD attitudes between roles, results indicated that compared to PIs, all other role subgroups reported lower outcomes and those of both the graduate student and extension subgroups were significant.

## **Introduction**

### **Transdisciplinary overview.**

Traditional methods of scientific research have historically resulted in individuals representing disciplinary roles advancing scientific discoveries. Discipline-based research has contributed to immeasurable scientific achievements (Stock & Burton, 2011) and provided scientists a uniform frame of reference and language (Petts, 2008). However, a developing method of research, which crosses disciplinary boundaries, has emerged in the last few decades (Kessel et al. 2008; Stokols et al. 2005; Stock & Burton, 2011, Wuchty, 2007). Addressing the complex problems of today call upon more collaborative methods for scientific research. This collaboration requires scientists to co-mingle disciplines to assess system-wide problems, and develop research agendas to address them.

This new scientific approach, also known as team science, is defined as a collaborative effort to address a scientific challenge that incorporates the strengths and expertise of professionals from a variety of scientific backgrounds. The theory behind team science is based on the idea that consolidating experts across various fields of study to analyze and explore complex problems may likely result in better scientific outcomes.

Integrating scientists from multiple disciplines can result in varying levels of collaboration. Research can be multidisciplinary, interdisciplinary or transdisciplinary. Multidisciplinary refers to two or more disciplines collaborating on a common outcome, yet maintaining their own disciplinary perspectives and methods (Russell et al. 2007). Interdisciplinary refers to the development of integrated knowledge and theory through the collaboration of multiple disciplines setting common goals (Tress et al. 2005). Transdisciplinary research (TDR) integrates researchers from different, unrelated disciplines and non-academic partners to research a common goal and create new theory and knowledge (Tress et al. 2002). Transdisciplinary research is often an issue-driven collaboration, which indicates that it is organized to address a particular issue or problem (Harris & Lyons, 2013; Robinson, 2008). It provides those involved with an opportunity to provide input and accept accountability for outcomes. This “logic of accountability” will presumably improve scientific relevance and accountability (Barry et al. 2008; Nowotny, 2001; Donaldson, 2010) and generate additional feedback loops to influence research questions and outcomes.

Technological advances over the past few decades have supported the increase in transdisciplinary efforts. Opportunities to collaborate through advances in technology via the Internet, web meetings, and data sharing allow TDR be more accountable, effective, result-oriented, and policy driven (d’Andrea, 2009).

Transdisciplinary research requires a collaboration of multiple disciplines and a melding of distinctive frameworks and methods (Brandt et al. 2013; Stock & Burton, 2011; Wright Morton et al. in process). It is considered the highest level of collaboration among scientists and necessitates an integration of ideas, knowledge, theories, and methods to create new ways to research and potentially solve complex problems (Stock & Burton, 2011; Brandt

et al. 2013; Tress et al. 2002). The potential benefits for this level of scientific integration is appealing, but there are challenges as well.

The remainder of this section examines why these complex scientific collaborations are important and the potential challenges and benefits of such projects. The next section offers an extensive literature review, summarizing key literature, and providing insights into key variables in this study. The statistical analysis employed for this study is outlined in the Methods section, followed by a Results section. Finally, a Conclusion section offers a summary of the study and next steps for TDR.

### **Transdisciplinary science- potential benefits.**

Transdisciplinary science is unique due to its merging of experimental and applied research with the expectation that this participatory approach will create greater societal benefits. Optimism for quality outcomes created by this integration of scientific knowledge makes TDR the goal for research projects both large and small. Funding agencies are also becoming increasingly aware of the potential for TDR projects and often actively seek transdisciplinary proposals. Whether governmental or private, these agencies are tasked with conducting research that will provide insights into some of our most pressing issues.

Competition for diminishing funds requires those in the field of team science to prove its impact on scientific advancements (Roux, 2010). The National Science Foundation (NSF), for example, solicits proposals that merge multiple actors. Additionally, the National Institute of Health (NIH), another top funding agency, has created multi-center initiatives intended to promote collaborative research and training (Hall et al. 2008).

In addition to the prospect of better scientific outcomes (Pohl, 2011), TDR can have a positive impact on participants, their disciplines, and those students involved (Harris &

Lyons, 2013) by offering greater visibility in the scientific community (Goring et al. 2014) and through the creation of professional relationships through networking opportunities (Katz & Martin, 1997).

### **Transdisciplinary science- potential challenges.**

While TDR methods may offer advancements in the scientific field, conflicts may arise between the benefits the TDR approach and the potential costs of such collaborations (Cummings & Kiesler, 2005). Throughout the development and implementation of the transdisciplinary project, potential challenges may occur. In isolated disciplinary work, “professional cultures” (Harris & Lyons, 2013) and cognitive cultural similarities (Klein, 1996) exist to form a bond among group members that can make collaboration across disciplines more challenging. Inversely, too much similarity among scientists can be unfavorable as well and may suppress creativity and lead to “group think” (Rhoten, 2003). Finding the appropriate balance between cohesion and diversity is a critical step in TDR development (Stokols, 2005). A significant barrier in integrating disciplines is a differing communication and language framework (Stock & Burton, 2011), and differing methodologies (Harris & Lyons, 2013). To overcome such barriers, all parties involved must communicate and identify research goals and merge their respective knowledge and methodologies to create new strategies and techniques towards problem solving. Other challenges cited in the literature include: conflicting goals among TDR team members (Bruneel, 2010), dispersed geographical locations of project participants (Stokols, 2008; Cummings & Kiesler, 2005), competition for diminishing funds (Roux, 2010), and difficulty in reproducing research (Brandt et al. 2013).

**Paper overview.**

Although the TDR framework is still relatively new compared to the well-tested traditional scientific method of research, the potential for improved outcomes presents opportunities for studying effective TDR development. Addressing both the challenges and benefits of integrated science will likely produce better outcomes and serve as a framework for effective TDR projects of similar size and complexity. Research questions must advance the field TDR and produce empirical evidence for on-going, effective TDR development.

Ultimately, we strive to understand what factors predict positive TD behavior. However, to explore TD behavior, we must first study critical antecedents to behavior engagement, TD attitudes. The reasoned action model developed by Fishbein & Ajzen (2010) provides a framework for understanding behavior. They hypothesize that intention is a major predictor of behavior, and that attitude towards the behavior is a critical factor in the formulation of an individual's intentions. To that end, this paper explores attitudes towards a large transdisciplinary research project from a participants' perspective over time. This longitudinal panel study analyzed evaluation survey data from the Climate and Corn-based Cropping Systems Coordinated Agricultural Project, or CSCAP. Through the analysis of evaluation survey data, the following research question was addressed:

(1) What factors are associated with changes in attitudes toward transdisciplinary research over time?

## **Research on Transdisciplinary Science**

### **Evaluation of transdisciplinary projects.**

To establish TDR as a viable scientific method, evaluative studies are necessary to validate their effectiveness for ongoing financial and researcher support (Stokols, 2003). However, due to the collaborative nature of TDR, significant barriers exist which complicate the evaluation of such projects (Stokols et al. 2003). For instance, standard and consistent evaluation processes don't currently exist due the hybrid nature of the combined research team. Additionally, determining the appropriate time frame to evaluate project outcomes is difficult because results can often take years to be realized. Moreover, the evaluators of the integrative research teams are likely non-neutral parties and maybe involved in the project itself, or have an investment in the results.

To date, most of the TDR studies have focused on the outcomes in the latter stages of the project. However, exploring additional aspects of TDR are necessary. For example, a study at the National Cancer Institute evaluated the collaborative-readiness of transdisciplinary projects. Through an analysis of the Transdisciplinary Research Energetics and Cancer (TREC) initiative, researchers explored the collaborative readiness of participants at the outset of the project (Hall et al. 2008). Several factors were identified as measures of "collaboration-readiness" that influenced teamwork in the initial stages of transdisciplinary projects. Grouping these antecedent factors into three categories provides a framework for understanding their influence. The categories are: contextual-environmental, which addresses the infrastructure considerations such as institutional supports/barriers environmental proximity, and electronic connectivity; intrapersonal characteristics which addresses research orientation and leadership qualities; and interpersonal factors which addresses group size, the

variety of disciplines represented, and the researcher's histories in previous transdisciplinary projects. Utilizing this framework to effectively launch a large collaborative project is important (Hall et al. 2008), however, the authors contend that evaluation should occur throughout the project (Stokols et al. 2003). Readiness levels can be influenced and reinforced through increasing antecedent conditions, but should also maintain a level of adaptability to adjust to all the variations in project integration (Klein, 2008).

Large collaborative projects are multi-faceted and require an assessment at multiple levels. A transdisciplinary research literature review done by Klein (2008) revealed seven generic principles for transdisciplinary evaluation as shown in table 1.

Table 1. Seven generic principles of transdisciplinary evaluation (Adapted from Klein, 2008)

Principle	Evaluative measure
1. Variability of goals	Evaluation of goals based on merging of disciplines
2. Variability of criteria and indicators	Evaluation of criteria and indicators created from the integrated team
3. Leveraging of integration	Evaluation of the quality of the integration process
4. Interaction of social and cognitive factors in collaboration	Evaluation of the mutual knowledge gained from intellectual and social integration
5. Management and coaching	Evaluation of leadership, organizational structure, networking, and communication
6. Iteration in a comprehensive and transport system	Evaluation of input opportunities and transparency
7. Effectiveness and impact	Evaluation of outcomes

This paper utilized several key collaboration scales and one scientific integration scale as identified by the TTURC survey (Mâsse, 2008) to address principles three through seven. The CSCAP evaluation survey collected data on attitudes toward transdisciplinary research, satisfaction with collaboration, impact of collaboration, and trust and respect. Transdisciplinary behavior, an element of principle four, was also evaluated through the assessment of collaborative activities (Hall et al. 2008). Because principle one and two are

better assessed during the development phase of the project we did not include them in our current study.

As we have stated, evaluating the outcomes of TDR is necessary to secure its place as a practical scientific method. This paper offers a unique perspective and attempts to analyze a transdisciplinary project from the perspective of the research participant. Considering the views and attitudes of those engaged in transdisciplinary work is an important evaluative tool. Participants provide researchers with an awareness of this challenging process while identifying individual barriers and incentives for doing so. Understanding these participant views and how they may evolve during the life of the project can guide project leaders in adapting resources or outcomes for optimal impact.

Although the momentum of TDR is substantial, there are critics of this scientific process who often highlight the difficulty in proving its effectiveness. Benefits from project outcomes can sometimes take years to develop and manifest (Stokols, 2008). This delay in achieving project outcomes is problematic for funders who expect to receive evidence that their funding choices are appropriate and successful, and for project members who wish to experience the satisfaction of scientific advancement.

### **Conceptual background and framework.**

The conceptual background for this study draws on research conducted for two major NIH-funded transdisciplinary research projects: 1) Transdisciplinary Tobacco Use Research Centers (TTURC), and 2) Transdisciplinary Research on Energetics and Cancer (TREC) initiatives. These innovative initiatives were key contributors to the development of the framework to evaluate TDR projects. The TTURC and the TREC were among the first to



evaluate the perspectives of the participants who work in these complex networks of scientists and stakeholders.

The CSCAP evaluation focused on several dimensions that TTURC and TREC research determined were key components of TDR. To guide the analysis for this paper, we employed an adaptation of the conceptual framework developed by Mâsse et al. (2008) and examined participants change in perspective and experiences with TDR over time. Figure 1 shows the relationships between the key dimensions of TDR that are conceptualized as predictors of project outcomes over time.

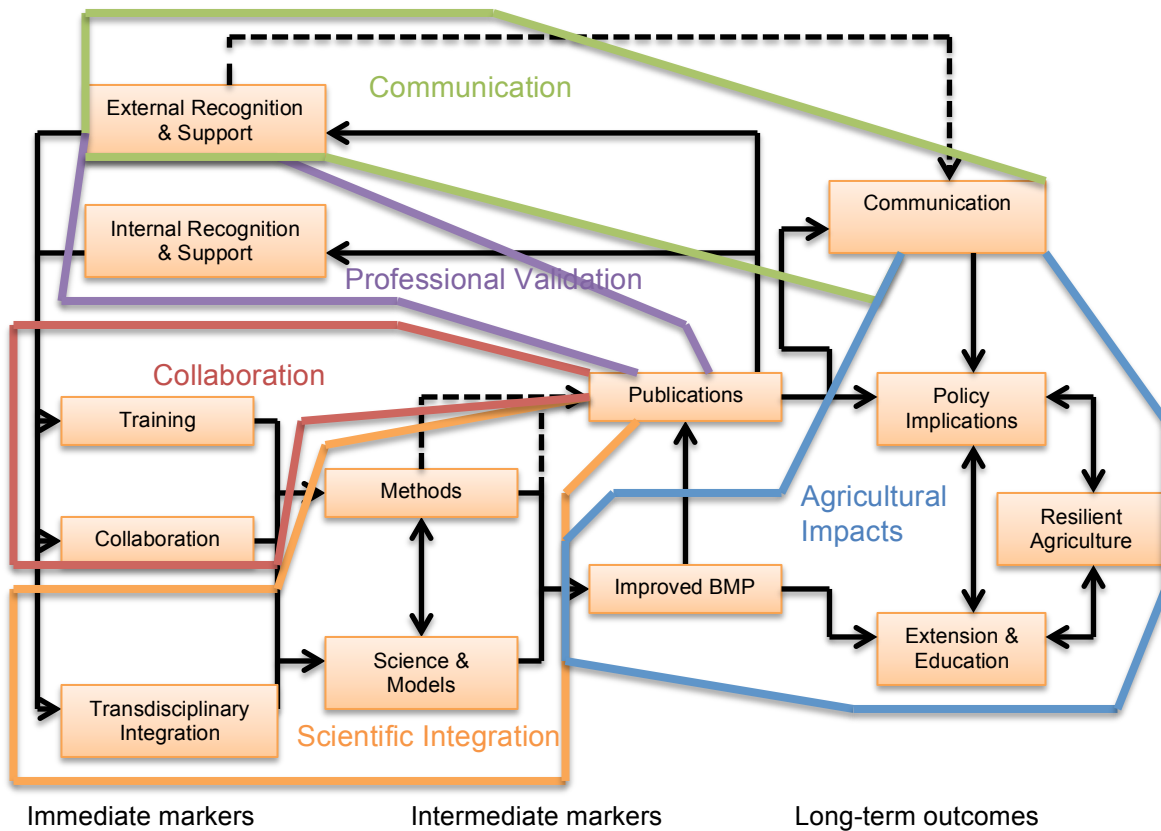


Figure 1: CSCAP Conceptual Model (Adapted from Mâsse 2008)

The CSCAP evaluation research focused on the collaboration and scientific integration concepts of the model. To examine the collaboration element, the evaluators drew

on concepts introduced by Hall et al. (2008). As Hall et al. (2008) describe, there are several “collaborative readiness,” factors that either support or limit effective teamwork and provide indicators for long-term project success. The collaborative-readiness factors are: 1) contextual-environmental conditions (e.g., institutional resources, technical infrastructure); 2) intrapersonal characteristics (e.g., research orientation, leadership quality); and 3) interpersonal factors (e.g., history of PI collaboration, team size, variability of team disciplines). For the purposes of our study we focus on factors two and three, which reflect the human dimensions of TDR and are more likely to be influenced over time (Hall et al. 2008).

Transdisciplinary integration is a key aspect in the scientific integration sector of Figure 1. Scientific integration at the TDR level requires scientists from different disciplines to merge knowledge and skill sets.

**Project Description: Climate and Corn-based Cropping Systems Agricultural Project (CSCAP).**

The CSCAP project, funded by the USDA National Institute for Food and Agriculture (NIFA), was a five-year, \$20 million project designed to research strategies for increasing the resilience of corn-based cropping systems to adapt to changes in climate. The project had four overarching goals: 1) retain and enhance soil organic matter and nutrient and carbon stocks 2) reduce off-field nitrogen losses that contribute to greenhouse gas emissions and water pollution 3) better withstand droughts and floods 4) ensure productivity under different climatic conditions.

The CSCAP project crossed nine midwestern states, 11 land-grant universities, and approximately 35 field sites. It integrated scientists across many academic disciplines, and

representatives from a variety of key stakeholder groups (e.g., farmers, agricultural industry, and NGO's), all who partnered in this unique and complex collaboration. The project was an excellent model for transdisciplinary evaluation as it provided a strong example of an issues-driven collaboration as it related to the complex interactions of climate and sustainability (figure 2). Additionally, it included various non-academic entities, which is an element of transdisciplinary research that separates it from other collaborative efforts.

Ultimately, the objective of this TDR project was to build a high-functioning, regionally coordinated network of science-based research, extension, and education that informed decision and policymaking regarding climate change and agriculture in the Midwest. (CSCAP 4 year report, 2014).

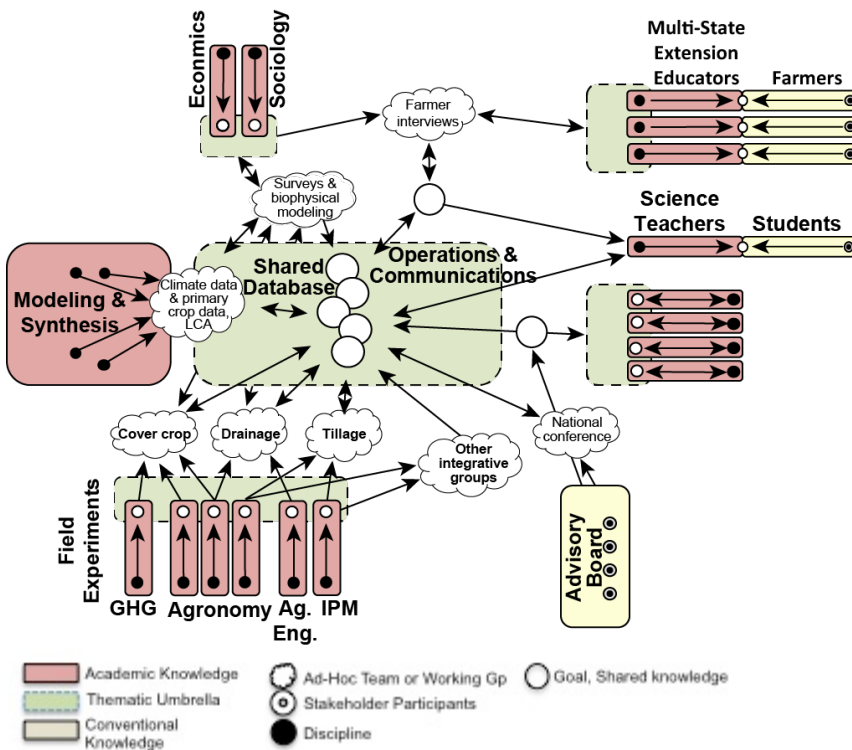


Figure 2. CSCAP Project: Transdisciplinary science model

**CSCAP participants.**

All CSCAP project participants and collaborators were members of one or more teams. Each team represented various objectives of the project and focused on one of two areas, research or support. The majority of project participants were assigned to the research-oriented teams which included the following: 1) Field/Research team (developed methods for monitoring carbon, nitrogen and water footprints at field sites all over the Midwest); 2) Analysis and Predictive Modeling team (integrated climate and economic data into a shared database for life-cycle analysis and modeling); 3) Social and Economic Research team (elicited farmers' beliefs and concerns regarding climate change, their attitudes regarding mitigation, and decision-making supports); 4) Extension team (promoted knowledge exchanges between farmers and Extension team members); 5) Education team (developed educational materials and opportunities to students at all levels from high school to graduate school). These teams were comprised of individuals who represented different roles within the project. Often, with differing roles also came different project responsibilities, and status within the project. The roles that were evaluated for this study are detailed below.

**Principal Investigators.** The project had approximately 50 PIs, who assisted in the initial grant development, served as mentors to the graduate students, and provided leadership to the entire research effort. As part of the leadership team, PIs were involved in the project from the beginning and were expected to provide leadership for the duration of the project. Due to their leadership and mentoring responsibilities, the PI role was chosen as the reference category for our multiple regression model. We wanted to compare TD attitudes for the PIs the other role subgroups.

Professional & Technical Staff. The role of Professional & Technical Staff was largely scientific. These 27 researchers were commonly hired by PIs to assist with the daily scientific work of the project and to serve as active members of the project team.

Graduate Students. The role of Graduate Student was one of scientist in training and included approximately 47 students from various Master and Doctoral programs across eleven institutions. As students graduated, other students were recruited to help advance the project directives and become discipline-based scientists trained to collaborate across disciplines. As of 2014, 83 graduate students contributed to the CSCAP project and gained valuable experience as next generation scientists. Four years into the five-year project, graduate students were involved in the publication of 19 articles in which they authored or co-authored. In one such article, CSCAP students reflected on their unique role and potential impact on the field of TDR by stating, “We are on the frontier of a transformative era of new science, based on a changing scientific landscape that will demand greater transdisciplinary efforts and team science... Therefore students are part of a natural experiment—a practical exercise in new research territory—in how the next generation of scientists will be trained and maneuver in a transdisciplinary environment” (Basche et al. 2014).

Advisory Board. The CSCAP advisory board served as an external voice in guiding project development and implementation. The collaborative environment of the CSCAP project benefited from the leadership of the 19 member advisory board based on their wide range of proficiencies including: agricultural production, scientific research, and executive management. As key members of their professional communities, they also helped network the numerous stakeholders involved. Stakeholders included representatives from the

agricultural industry, research centers, agricultural crop boards, federal and state interests, non-profits, and producers representing several midwestern states. The advisory board team consulted with the executive team via a monthly teleconference call, and networked with all team members at the annual meeting. Including the stakeholders in the entire TD process was necessary to advance this research effort from an interdisciplinary project to a transdisciplinary one.

Extension Educators. There were 18 extension educators actively involved in this project. They, through the nature of their work, have experience working in interdisciplinary settings and offered a professional perspective, rather than that of a researcher. Extension team members translated the science and provided the critical link between the researcher and the stakeholder. One of the main directives of the extension team was that of outreach. Throughout the project they coordinated focus groups, one-on-one discussions, field days, and publications. They promoted an exchange of information and knowledge between CSCAP participants that reached close to 7000 farmers, crop consultants and other extension personnel. Additionally, extension team members introduced strategies to promote farmer-to-farmer learning and implementation of appropriate management approaches.

Although the majority of team members were assigned to research-oriented teams, there were several support-oriented teams. For example, the Staff/Operations team provided operational support to all project members.

Face-to-face meetings are considered an integral part of effective communication and to building and maintaining cohesiveness and trust among team members (Eigenbrode et al.

2014; Hampton & Parker, 2011; Stokols, 2003). Due to the geographic challenges of the highly dispersed team, face-to-face meetings were limited. However, consistent communication was expected and achieved through a variety of methods. Face to face meetings did occur annually at the project conference, and more informally at each academic institution when possible.

Additional communication methods included regular team phone calls using Adobe Connect. This technology allowed participants to view shared documents and interact live with other team members. All project participants were encouraged to be involved in the whole-team meetings held every other month to discuss broad scope agenda items. In addition, the leadership team held monthly phone meetings. Each research team also had regular contact either through a monthly teleconference, or through face to face meetings when practical. A series of webinars was offered each year to provide professional development training for the next generation of scientists (graduate students). A graduate student workshop is scheduled near the end of the project timeline to provide direction towards their next steps as students and professionals.

Communication via email and shared material on the CSCAP website ([sustainablecorn.org](http://sustainablecorn.org)) provided another avenue for team members outside of academia to be actively involved and access research and other pertinent information in a timely manner. The website also contained resources such as fact sheets and research summaries to communicate the methods and objectives of project teams.

**Survey sample.**

A CSCAP evaluator, in collaboration with project leadership, developed a survey to measure project participants attitudes, beliefs and actions related to climate change. Data for this study were drawn from the 2011 and 2013 (pre-assessment and mid-assessment) survey.

In November of 2011, as the project was ramping up, a baseline evaluation survey (pre-assessment) was administered via email to 140 project participants. From those 140 eligible participants, 121 completed the survey. Project participants who joined the project after the initial survey distribution were also asked to complete it as they joined the project, and their scores were added to the baseline data. Twenty-three out of 29 eligible participants were added to this baseline for a total of 143 respondents.

In July of 2013, at the third annual meeting, which took place about 2.5 years after the project received its first funding, a mid-term assessment was administered to all project participants via email (n=157). Of the 157 eligible participants, 84 completed the survey. To create a longitudinal panel study, only those individuals that participated in both the pre and mid-assessment were used in the final sample (n=75). Seven of those 75 had selected “other” as their project role. Because we employ project role as an independent variable, and the role of “other” was not well defined, these observations were dropped, resulting in a final longitudinal panel sample consisting of 68 project participants who took both surveys.

To test for non-response bias we compared year one (pre-assessment) non-respondents’ scale means to respondents’ scale means. Non-respondents were identified as individuals that participated in either the pre- or mid-assessment survey, but not both. We conducted independent samples t-tests to compare means for all of our variables of interest.



No statistically significant differences were identified between respondents and non-respondents.

The CSCAP evaluation survey items were developed to evaluate project participants' perspectives over time and drew heavily on a combination of both the TTURC and TREC survey. Under the collaboration category, measures of collaborative behaviors, satisfaction with collaboration, impacts of collaboration, and trust and respect were adapted from the TREC initiative (Hall et al. 2008). Measures of attitudes toward transdisciplinary integration were developed primarily from TTURC survey items (Mâsse et al. 2008).

### **Research objectives.**

A number of key characteristics converge to build the foundation for effective TDR. Several studies, mostly qualitative in nature, have explored the necessary methods to identify and measure effective project characteristics and post-project outcomes. Results of these studies have linked project success to the following components: interpersonal skills such as communication and social engagement (Katz & Martin, 1999; Stokols, 2003; Kessel, 2008; Cheruvelil, 2014), team diversity (Cheruvelil, 2014; Roux, 2010; Hampton & Parker, 2011), discipline integration (Wickson, 2006; Kessel, 2008; Hampton & Parker, 2011), commitment to shared goals (Cheruvelil, 2014; Kessel, 2008), transdisciplinary ethic (Stokols, 1999) and trust (Kessel, 2008; Hampton & Parker, 2011; Harris & Lyon, 2013).

Until a series of studies from 1999 to 2004 by Stokols et al. (2005), few had systematically assessed the experiences of participants over time. Stokols et al. (2005) published a longitudinal study based on outcomes at multiple TTURC centers that analyzed collaborative processes and outcomes. Our study coupled a longitudinal analysis with an examination of relationships between collaboration variables in geographically dispersed

teams. To our knowledge, no research has examined how project participants' perspectives might change over the course of project participation in such a diffuse team environment.

Due to the interactive environment of TDR projects, understanding participant experiences is important to reflect on when considering the long-term sustainability of such projects. The theory behind participant evaluation is quite simple. Project members may be more inclined to participate in future TDR projects if their current or past experiences are positive as well. Moreover, those having a positive experience may be more willing to engage in projects at the leadership level, or offer their expertise as a mentor for next generation scientists. This analysis hopes to contribute to the science of TDR by providing the participant perspective. Given the interpersonal nature of TDR and the typical length of these projects, it is important to understand the factors associated with variation in participants' attitudes and beliefs towards such projects. Through analysis of participant survey data, this study examined the perspectives of people who were actively involved in the transdisciplinary process and attempted to answer the following research question: What factors are associated with changes in attitudes toward transdisciplinary research over time? As the project matures, we anticipate that attitudes about the process of collaboration will change as relationships within the project develop, and project milestones and objectives are met (or not). Developing a framework for better understanding of how participants' perspectives change over time, and the degree and direction of changes could inform future project management approaches.

## **Methods**

### **Measures.**

Five question sets were employed to measure general attitudes toward transdisciplinary integration and collaboration. Four of these question sets were derived directly from a logic model developed by Trochim et al. (2008) following an extensive concept-mapping exercise to identify key constructs associated with effective TD initiatives. The logic model introduced critical factor structures in transdisciplinary research identified by TD participants and validated through the TTURC study (Mâsse et al. 2008). The fifth question set was developed to assess transdisciplinary behaviors. Transdisciplinary behaviors are markers for “collaborative readiness” and are determinants of collaborative capacity (Hall et al. 2008). All five question sets are considered early markers for effective TDR. It is expected that higher scores in these measures would indicate a more positive TDR experience and capacity for collaboration, which would ultimately result in increased outcomes. In addition, we expect that higher scores in the areas of TD behavior, satisfaction with collaboration, impact of collaboration, and trust and respect may have an impact on the overall attitude a participant has towards TDR.

The first question set measured participants’ attitudes toward transdisciplinary integration. The other four question sets measured varying aspects of collaboration and included the evaluation of collaborative behaviors, satisfaction with collaboration, evaluation of the impacts of collaboration, and trust and respect among project participants. All five question sets were administered at two points in time, the pre-assessment and the mid-assessment. From these identified measures, we created a multiple regression model to

examine the relationship between TD attitudes and measures of collaboration. Additionally, we wanted to explore the possible relationships between the participant roles, and gender.

***Transdisciplinary attitudes.*** Transdisciplinary attitudes were measured by evaluating the extent to which participants' agreed with basic characteristics of transdisciplinary science. The question set included items which measured the participants' individual attitude towards TDR, and their perspectives on the value of team collaboration as a whole. A full list of survey items is presented in table 2. Transdisciplinary science was defined using Rosenfield's (1992) conceptualization. All 11 questions were drawn from the TTURC survey (Mâsse et al. 2008). Minor revisions were made to better align with the specific language of the CSCAP project. A 5-point scale was utilized, ranging from strongly disagree (1) to strongly agree (5), with 3 being "neutral." A sixth response category, "don't know," was also included (6). For this study we chose TD attitudes as the dependent variable in the multiple regression analysis. Behavioral research suggests that attitude is a critical determinant in whether or not an individual engages in a particular behavior (Fishbein & Ajzen, 2010). Therefore, we proposed that a positive attitude towards TDR could impact where or not an individual engages in current and future TD projects.

Table 2. Transdisciplinary attitude: individual survey items

I describe myself as someone who strongly values transdisciplinary collaboration
Transdisciplinary research in the CSCAP stimulates me to change my thinking
I have changed the way I pursue research ideas because of my involvement in the transdisciplinary CSCAP
Transdisciplinary research has improved how I conduct research
CSCAP team members are open-minded about considering research perspectives from disciplines other than their own
I am optimistic that the transdisciplinary research of the CSCAP will lead to valuable outcomes that would not occur without this kind of collaboration
Addressing issues through a transdisciplinary team approach results in better research, education, and outreach
Because of my involvement in transdisciplinary research, I have an increased understanding of what my own discipline brings to the collaboration
Generally speaking, I believe that the benefits of transdisciplinary scientific research outweigh the inconveniences and costs of such work
I am comfortable working in a transdisciplinary environment
Overall, I am pleased with the effort I have made to engage in Transdisciplinary research for the CSCAP

***Collaborative behaviors.*** Adapted primarily from the TREC “collaborative activities” scale (Hall et al. 2008), the collaborative behaviors items measured the frequency with which CSCAP team members actively participated in transdisciplinary behaviors outside of their primary discipline. The survey asked participants to indicate how frequently they participated in a series of eight behavior-related items. Participants responded on a five-point scale (“Never”, “Once or twice a year”, “Quarterly”, “Monthly”, or “Weekly”). Six of the items were drawn directly from the TREC study. Two additional items were created by CSCAP personnel to measure grant proposal activity. Grant writing and development is considered to be an important indicator of transdisciplinary collaboration in the realm of agricultural research. The behaviors selected for evaluation were established to represent actions beyond those of traditional disciplinary. A full list of survey items is presented in table 3.

Although in a previous study by Frescoln & Arbuckle (in process), TD behavior was not found to increase from the initial assessment to the mid-point assessment, this current

study incorporated this variable for several reasons. The first, we hypothesize that a statistically significant change in behavior may still be seen over time, but the pre to mid-project time frame was not adequate to show such differences. We expect that the post-assessment may reveal such changes. In addition, we suggest that it may also be possible for behavior to change before an attitudinal shift occurs under certain circumstances. For example, project participants may have been required to engage in TD behaviors based upon their role in the project rather than a positive attitude towards the transdisciplinary process. This active engagement may provide participants with an opportunity to experience the benefits of TDR, resulting in a positive shift in attitude.

Table 3. Collaborative behaviors: individual survey items

Pre: Prior to January 2011 (the start of the CSCAP), how frequently did you do each of the following?
Mid: During your participation in the CSCAP project, how frequently have you done each of the following?
Read journals or publication outside your primary, secondary, or third disciplines
Attended meetings or conferences outside your primary, secondary, or third disciplines
Participated in working groups or committees with the intent to learn from researchers in other disciplines
Submitted grant proposals, <u>other than the CSCAP</u> , in partnership with colleagues or others outside your primary, secondary, or third disciplines
Received grant funding rewards, <u>other than the CSCAP</u> , in partnership with colleagues or others outside your primary, secondary, or third disciplines
Obtained new insights into your own work through discussion with colleagues from other disciplines
Modified your own work or research agenda as a result of discussions with colleagues from other disciplines
Established links with colleagues from other disciplines that led to or may lead to future collaborative work

***Satisfaction with collaboration.*** Six items, drawn from the collaboration dimension of the TTURC survey (Mâsse et al. 2008), measured satisfaction with collaboration and team cohesiveness. The survey asked CSCAP participants to respond to statements about the CSCAP team on a 5-point scale ranging from strongly disagree (1) to strongly agree (5), with 3 being “neutral.” A sixth response category, “don’t know,” was also included (6). Five items were drawn directly from the TTURC study to examine team

cohesiveness, and one additional item was added by CSCAP staff to evaluate potential frustrations with fellow team members. To avoid problems identified in the TTURC survey with negatively worded questions (Mâsse et al. 2008), the decision was made to utilize positive language choices. The full text survey items are presented in table 4.

Table 4. Satisfaction with collaboration: individual survey items

<p>The CSCAP team is accepting of new ideas</p> <p>There is good communication among CSCAP team members</p> <p>The CSCAP team is able to capitalize on the strengths of different researchers</p> <p>The organization and structure of the CSCAP team is working well</p> <p>The CSCAP team is able to accommodate the different working styles of team members</p> <p>CSCAP team members are responsive to requests for information or action from other CSCAP team members</p>
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***Impact of collaboration.*** Six items measured the CSCAP participants' perceptions regarding the outcomes of the CSCAP project by evaluating productivity and quality. All six survey questions were drawn directly from the collaboration section of the TTURC survey (Mâsse et al. 2008). Most questions were adapted to align with language specific to the productivity and quality of the CSCAP project. The survey asked CSCAP participants to respond to statements about the CSCAP outcomes on a 5-point scale ranging from strongly disagree (1) to strongly agree (5), with 3 being "neutral." A sixth response category, "don't know," was also included (6). A full list of survey items is presented in table 5.

Table 5. Impact of collaboration: individual survey items

<p>The CSCAP group meetings are productive</p> <p>Overall CSCAP productivity (i.e., data, methodologies, modules, publications, and other products) is high</p> <p>Overall quality of CSCAP data, methodologies, modules, publications, and other products is high</p> <p>In general, the CSCAP has improved my research productivity (i.e., data, methodologies, modules, publications, and other products)</p> <p>In general, the CSCAP has improved the quality of my research</p> <p>Time spent of the CSCAP is well worth the effort in terms of returns I am receiving</p>
--

***Trust and respect.*** Six items measured participants' trust and respect towards their fellow CSCAP team members. Participants responded by assessing the degree to which they were willing to take risks by voicing their opinions and accepting constructive criticism without concern about negative consequences. Four survey questions were drawn directly from the collaboration section of the TTURC survey (Mâsse et al. 2008). Two additional items were added by CSCAP personnel to assess possible concerns about appropriation of ideas and comfort in sharing thoughts and ideas with an integrated audience. A 5-point scale was employed, ranging from strongly disagree (1) to strongly agree (5), with 3 being "neutral." A sixth response category, "don't know," was also included (6). The full text survey items are presented in table 6.

Table 6: Trust and respect: individual survey items

I am comfortable showing limits or gaps in my knowledge to CSCAP team members
In general, I feel I can trust the CSCAP team
In general, I find the CSCAP team members are open to constructive criticism
In general, I respect the CSCAP team members
I trust other CSCAP team members will not exploit or otherwise misappropriate ideas or information I share
I feel comfortable voicing my thoughts, knowledge, and opinions during CSCAP meetings and conference calls

### **Participant roles.**

The roles variable was measured by offering seven different roles and asking the participant to choose the role that best fit their responsibilities. The roles offered to respondents included: "PI"; "Professional & technical staff"; "Graduate Student"; "Advisory Board" and "Extension Educator". This question was asked for the pre-assessment and not the mid-assessment. It was assumed that roles would not change during the time period between assessments. The percentage distributions by role are as follows: PIs (36.8%), professional/technical (14.7%), graduate student (30.9%), advisory board (5.9%) and



extension (11.8%). These are entered into the model as four dummy variables (1=yes, 0=no), with PI as the reference category.

### **Gender.**

Gender was measured for project participants at the initial assessment only. Respondents were offered the following options, “Male” and “Female”. All participants responded and the following percentages were reported: 68% Male and 32% female.

### **Analysis.**

*Analytical approach.* To evaluate changes over time, pre-assessment data and mid-assessment data were compared utilizing a longitudinal panel design. We analyzed results for only those participants who completed both the pre- and the mid-assessment (n=68). A multiple regression analysis was employed to assess the relationship between the dependent variable, TD attitude, and the independent variables which are: role, gender, TD behavior, satisfaction with collaboration, satisfaction with impact, and trust/respect.

*Change score creation.* Four of the five question sets utilized a 5-point scale ranging from “strongly disagree” (1) to “strongly agree” (5). A “neutral” (3) and “don’t know” (6) category was also included. The choice was made after the initial data analysis to combine variables and create a three-point scale in which the “neutral” and “don’t know” variables were pooled to form a “not agree” category. This was decided because 1) we had so few respondents in the “disagree” category (~1-2%), 2) no respondents in the “strongly disagree” category, and 3) because our sample size was small, we did not want to lose any observations by dropping the “don’t know” category. We considered combining the “neutral” and “don’t know” categories, but decided that this would entail an assumption that the two categories measure the same concept. Combination of the “disagree”, “neutral”, and “don’t

know” categories into a single “not agree” category facilitated detection of changes between “agree” and “not agree” categories. This resulted in a three-point scale from not agree (0), agree (1) and strongly agree (2). Summated scale measures were created for all of the conceptual areas. The transdisciplinary behavior question set measured behavior on a five-point frequency scale ranging from never (1) to weekly (5), and thus was not converted into a 3-point scale.

Because attitudinal constructs are complex and multidimensional, summated rating scales are often considered to be better for attitude measurement than multiple single-item scales (DeVellis 2003; McIver and Carmines 1981; Spector 1992). Use of summated scales that combine multiple single-item scales to measure attitudinal constructs can improve both reliability and precision of measurement, and address collinearity between closely related items that measure latent constructs (Field 2009). The four scales comprised of the recoded agreement scales were constructed by summing the 3-point (not agree, agree, strongly agree) items then dividing the sum by the number of items (DeVellis, 2003; McIver, 1981). The Cronbach’s alpha reliability coefficients (denoted by  $\alpha$ ) were all higher than .792 (table 7).

Table 7. Transdisciplinary scale results for collaborative behaviors and TD integration measures

	Pre-assessment			Mid-assessment			Change score			
	Mean	SD	$\alpha$	Mean	SD	$\alpha$	Mean	Min.	Max.	SD
Transdisciplinary attitudes	9.67	5.03	.878	11.27	4.87	.877	1.68	-7.00	15.00	4.31
Collaborative behavior	19.13	5.40	.814	18.48	4.67	.792	-.68	-10.00	9.00	4.18
Satisfaction with collaboration	4.10	3.51	.883	5.81	3.18	.846	1.37	-6.00	12.00	3.69
Impact of collaboration	3.10	3.07	.839	4.80	3.28	.893	1.65	-6.00	10.00	3.11
Trust and respect	5.34	3.37	.876	7.16	2.86	.837	1.79	-4.00	11.00	3.31

The final step in scale creation was to calculate the differences in the scales between the pre and mid- assessment. To report the change values, we subtracted the scale score of the pre assessment from the scale score of the mid-assessment. These values are reported in

Table 7. As Table 7 shows, the means for the change scales are small, but the range is quite large. All change scores were positive with the exception of TD behavior, which showed a negative change from the pre to mid-assessment.

## Results

The multiple correlation coefficient between our selected variables and TD attitudes shows a good model fit with a reported F-ratio of 5.146 ( $p < .001$ ). The adjusted  $R^2$  of .365 indicates that the independent variables in the model explain approximately 37% of the variance in the TD attitudes change scale.

Regression results indicated that out of the four reported change scales, there was only one that was statistically significant. A positive relationship between trust/respect and the participants' evaluation of TD attitudes ( $p < .05$ ) was evident. For the additional collaboration variables measured, all showed a positive relationship, but none were statistically significant.

Mixed results were also found for significant relationships comparing the reference category (PI) with other role subgroups (table 8).

Table 8. Linear model of predictors of TD attitude change.

	<i>b</i>	SE B	$\beta$	p
Constant	2.27	.78		$p = .005$
Professional/Tech vs. PI	-2.18	1.45	-.17	$p = .139$
Graduate Student vs. PI	-4.02	1.10	-.43	$p = .001^{**}$
Advisory board vs. PI	-1.10	2.09	-.06	$p = .603$
Extension vs. PI	-3.54	1.57	-.26	$p = .028^*$
Gender	.62	1.10	.07	$p = .580$
TD behavior	.22	.12	.21	$p = .070^a$
Satisfaction with team	.15	.18	.12	$p = .423$
Satisfaction with outcomes	.27	.22	.19	$p = .228$
Trust/respect	.41	.16	.29	$p = .014^*$

<sup>a</sup>  $p < .10$ , \*  $p < .05$ ; \*\*  $p < .01$ ; \*\*\*  $p < .001$

**Changes in TD attitude: behavior and collaboration scales.**

Previous analysis of the CSCAP longitudinal study was conducted to determine differences in participants' attitudes towards transdisciplinary science over time. The results are found in Figure 3 (Frescoln & Arbuckle, in process). Increases in attitude scores were present for the overall CSCAP team and for all subgroups, with the exception of the grad students. Statistically significant changes were found for the CSCAP team, PI, and advisory board subgroups. All other changes (prof/tech, graduate student, and extension) were not statistically significant.

Given the reported changes in attitude over time, our next step was to identify the factors that influence participants' attitudes towards transdisciplinary science. The results of the multiple regression analysis revealed that the only variable that showed a relationship with TD attitude, controlling for all other variables, was trust and respect ( $p < .05$ ). This positive relationship suggested that for every unit increase on the trust and respect scale, there was a .41 increase in TD attitude scores (table 8).

The multiple regression analysis also revealed a positive relationship between TD attitudes and TD behavior, satisfaction with collaboration, and impact of collaboration. However, none of these were statistically significant. Gender did not have an impact on TD attitude, either ( $p = .580$ )

**Changes in TD attitude- participant roles.**

Additional variables were included in the regression analysis to explore the relationship between participant role and TD attitudes. Results from the regression analysis revealed that relative to PI's (the reference category in the regression model), graduate students and extension personnel had significantly lower change scores ( $p = .001$ ;  $p < .05$ ). This

analysis revealed several interesting findings. On average PIs had a change score of 3.6 on the TD attitude scale. Graduate students, on the other hand, reported a negative change (decrease) in attitude scores of -1.2. Other role subgroup had the following change scores: extension (1.43), professional/technical (1.75), and advisory board (3.25).

## **Discussion**

Transdisciplinary projects due to their complexity in organization, implementation, and goals are often long-term commitments for those involved. Understanding how participants' perspectives change over time is critical to maintaining an effective project and producing relevant outcomes. This study built on a previous study (Frescoln & Arbuckle, in process), which identified participants' attitudes and beliefs towards TDR, and explored whether predictors of TD attitude can be identified. If researchers can identify the determinants of positive TD attitude, it follows that projects can be adapted as needed to provide resiliency under changing conditions and ultimately foster positive TD behavior change.

### **Trust and respect.**

There are several studies in the field of TDR that explore the importance of trust in building transdisciplinary teams (Harris & Lyons, 2013; Mâsse, 2008; Bruneel, 2010). This research supported those findings by providing evidence of a positive relationship between change in the trust and respect measures and changes in TD attitudes. It is expected that trust and respect build over time as project participants interact and form professional relationships towards a common goal.

### TD attitude and role.

The role and status of the PI provided a baseline to which we could compare changes in the other subgroups. Interestingly, at the mid-point assessment, the increase in attitude score by PIs and the decrease in attitude score by graduate students converged to reveal similar attitudes towards TDR (figure 3). This could suggest that graduate students, given more time and experience within a TDR project, began to assess collaborative work more realistically. For PIs, the results suggest that although they began the project with a positive attitude towards TDR, their engagement in the process increased their TD attitudes considerably.

To further illustrate how projects evolve over time, we look to changes primarily from third-party participants. Compared to PIs and in absolute terms, extension personnel reported a significant change (positive) in attitude scores, although at a lower rate. This is not an unexpected finding considering that PIs are more established in the research field than students or extension subgroups. It may take more time for role subgroups outside of PIs to build trust and network with other participants.

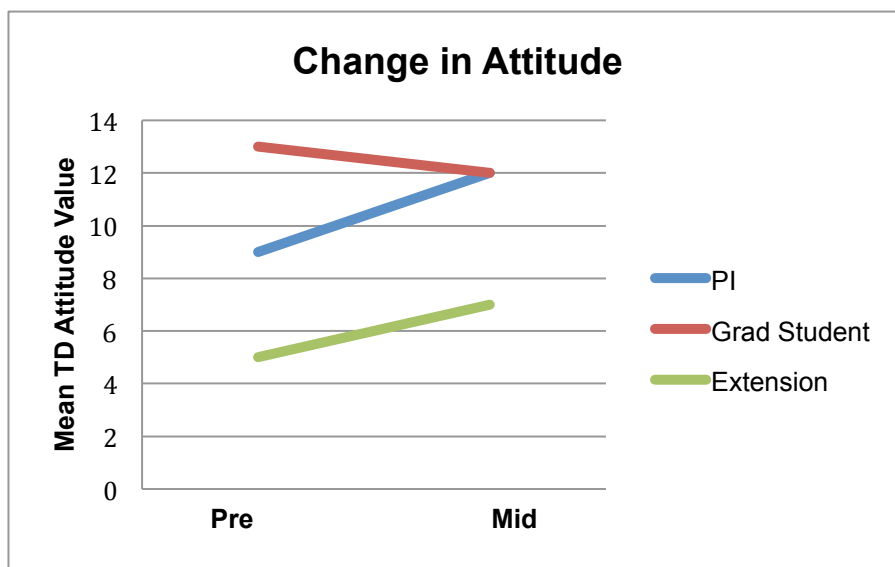


Figure 3. Change in TD Attitude between pre- and mid-assessment by role

In the TDR model, advisory board and extension professionals have the opportunity to give input and feedback. This is likely a new role for these participants and low pre-assessment scores on TD attitudes, satisfaction with collaboration, impact of collaboration, and trust/respect supports this initial caution in engaging in new and unfamiliar behaviors (Frescoln & Arbuckle, in process). However, in all of these reported measures, third-party participants scored higher at the mid-assessment point and all were at a significant level except for extension attitudes. This perception shift is critical because third-party participation is what separates TDR from other collaborative methods, and understanding how these participants engage in TDR work is essential for the long-term viability of such projects.

### **Conclusion**

The field of transdisciplinary research requires a systematic and empirical evaluation of its process and outcomes. While previous research has shed light on TDR areas such as challenges, benefits, common characteristics, and outcomes, there are gaps in our knowledge. This study, which utilized a large transdisciplinary project to examine participants' perspectives towards integrated research, provided a unique perspective on TDR and insights into changes in TD attitude over time. The goal of this study was to generate data that could assist leaders in adapting projects to accommodate participants' values and beliefs towards team science over the life of the project to produce the best possible outcomes

This exploratory research study sought to identify areas of change. What determines changes in TD attitude by participants over time? The CSCAP project evaluators collected participant research data, which provided us with a longitudinal data set to examine participants' attitudes and behaviors over time. The data set was comprised of 68 CSCAP

project participants who completed both the pre- and mid-assessment survey. A multiple regression analysis was employed to identify relationships between TD attitudes and the following key variables: TD behavior, satisfaction with collaboration, impact of collaboration, trust and respect, gender, and project roles. The results indicated that there was a positive relationship between TD attitudes and the trust and respect variable. Other significant findings were found when we compared the change in TD attitudes of the PI reference group to other role subgroups. Compared to PIs and in absolute terms, the graduate student and extension subgroups had lower change scores. This is not surprising when you consider that PIs, through the nature of their work as established researchers, may have a more optimal skill-set than those outside the direct research field (extension), or those just beginning their research careers (graduate students).

The scope of transdisciplinary research has expanded over the last few decades, but a gap for future research still remains. The role of the non-principal investigator has often gone unnoticed in past research endeavors (Stokols, 2003). If we are striving to truly understand process of effective TDR, it is necessary to examine the perspectives of all the actors involved. For example, graduate students can provide project leaders and evaluators with valuable insights into team development. Graduate students are in a distinctly difficult position as indicated by their decrease in TD attitude scores over time and lack of significant positive change on the other TD measures (Frescoln & Arbuckle, in process). They experience contrasting goals of establishing themselves in their disciplinary fields (Stokols et al. 2008) and participating in the growing field of collaborative science. In addition, academic pressure to produce research outputs, such as primary-authored publications, can be challenging for early-career researchers, especially for those involved in collaborative



research (Goring et al. 2014). Inconsistent training, both at the academic and individual level presents another challenge graduate students. It is not unusual for graduate students to be involved in multiple projects over the course of their academic career and it is possible that those studies could occur at more than one institution by the time they graduate, and post-graduate studies are complete (Goring et al. 2014). By comparison, the PIs are already established in their disciplines and likely to be working with colleagues of similar status. These differences in skill level, status, and professional establishment are likely factors that impact participants' perspectives towards TDR and are important to consider in the development and implementation of large collaborative projects.

The regression results for extension personnel also offered important insight to the non-principal investigator role. Under the traditional model of scientific research, the extension role is that of communicator. With the introduction of collaborative science, key players that were once outside the development of the research agenda are now being asked to provide input and direct outcomes. This changing role will require an intentional focus from project leaders to develop this new collaborative culture among those traditionally outside the research community.

The complexity of today's research agendas often requires them to be multi-year endeavors. It is possible, and likely, that these long-term projects will shift and change, either naturally or by intentional realignment (Wright Morton et al. in process). Using the results of this study and others like it, researchers have access to critical insights on significant shifts and changes that may occur over the life of the project. Ultimately, this could assist project developers and leaders in making informed decisions and choosing adjustments at key points in the project to reach project goals.

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## CHAPTER 4

## GENERAL CONCLUSIONS

“I am by nature and profession a person that asks questions whose answers must come from the interaction of many different sources. The problems I research are complex and stem from existing situations where no one discipline has been able to formulate or address the problem. In the case of CSCAP, studying the processes and theories employed by the leadership in order to develop a trans-disciplinary team has given me new perspective on how scientists whose philosophies, methods, and scientific paradigms conflict can and will make room for each other when the problem demands it.” (CSCAP survey respondent)

**Conclusion**

In the last few decades, there has been an evolution in the area of scientific research. As problems became multi-faceted and global, new scientific methods to address these problems have emerged. The result of this evolution has been a transition from traditional methods of research to more collaborative methods utilizing the knowledge of multiple disciplines to address complex problems from diverse perspectives. The highest form of collaboration, transdisciplinary research (TDR), is becoming a new framework for scientists to explore all aspects of the complex issues before them, and potentially produce more effective outcomes.



However, there are significant challenges associated with this more inclusive method. To diminish these challenges, evaluation studies on TDR have provided project leaders with important research and results to guide further development and refinement of the process. Past evaluative studies have largely focused on identifying the characteristics of effective teams, and project outcomes. This study, along with several from the TREC and TTURC initiatives, expanded the field TDR evaluation to include the perspectives of project participants. Understanding that TDR project teams are created from the integration of individuals from different disciplines, leaders are tasked with promoting an environment that fosters positive attitudes towards team science, as well as professional respect and trust. The CSCAP evaluation used in our studies provided participant data to inform decisions based on the human elements of TDR.

The participant data for the two studies was drawn from the CSCAP evaluation survey administered to all project participants at project initiation and at the mid-point. For the first analysis, we explored the following research questions: 1) Do participants' attitudes and behaviors toward the transdisciplinary process change over the course of the project? 2) Do these changes vary by participant role? The second analysis expanded on the initial research and presented the following question: Can we predict changes in transdisciplinary attitude over time?

Key variables were identified to measure these human elements of TDR. The variables for the first study included: TD attitudes, TD behavior, satisfaction with collaboration, impact of collaboration, trust and respect, and participant roles. A gender variable was added to the second study to explore possible relationships to attitude. Results

indicated that there were significant changes in the TD measures over time, differences can vary by role, and that trust/respect is a predictor of TD attitudes.

The results of these two studies provided a foundation for understanding participants' attitudes and beliefs regarding TDR, how these attitudes and beliefs may change over time, and factors that influence this change. A noteworthy result is that while the overall CSCAP team showed significant positive change on all measures excluding behavior, the changes by subgroups varied. In fact, the subgroup that consistently showed insignificant change for all but one measure was that of the graduate student. The one measure that was significant was a decrease in TD attitude from the pre-to mid-assessment. These were important findings and indicate that extra training and/or resources may be needed for graduate students to fully engage in TDR and experience the positive rewards of collaborative work.

At the macro-level, we assumed from previous behavioral research that an individual's change in behavior is preceded by a change in attitude towards that behavior. At the micro-level, we used this study to examine the factors that might instigate a change in attitude from project participants. In doing so, we found a significant positive relationship between TD attitudes, and the trust and respect measure. This finding supports the premise that in order to experience positive attitudes towards TDR, you need to trust and respect your project partners. Additional findings based on multiple regression analysis revealed that compared to PIs, other subgroups did not have the same rate of change over time.

### **Implications**

As leaders of large collaborative projects look to scientific evidence to guide the development of TDR, studies, which explore the human elements of these complex strategies, are valuable in developing approaches to promote effective collaboration.

Challenges from integrating multiple disciplines may be diminished by an intentional focus on developing research skill sets of third-party actors and fostering an environment of mutual trust and respect. Although graduate students are considered part of the academic research team, their responses reflect the unique position they hold. As next generation scientists, they have a stronger background in research than many of the stakeholders involved, however, their status as a student and learner may impact their satisfaction with the process of collaboration.

In summary, an increase in TD attitudes within a large TDR project was positively related to project participants' evaluation of trust and respect. However, not all project participants are created equally. The inclusion of stakeholders and other participants outside the traditional role of research makes TDR unique from other collaborative initiatives. Third-party perspectives are necessary to view research questions holistically, but based on these evaluative studies, they may need more initial training and/or networking opportunities to foster their TD attitudes.

### **Limitations and Future Directions**

The CSCAP evaluation provided an opportunity to examine transdisciplinary participants' perspectives within a large collaborative project in the field of climate change and agriculture. This built upon the foundation of TDR literature that has to date, largely focused on the medical field. Expanding the research to other scientific arenas will reveal characteristics that are consistent across the field of TDR and not just project unique.

Additionally, although the CSCAP project is large by most measures, utilizing a longitudinal panel study required evaluation of those participants who completed both voluntary surveys. Utilizing this method was necessary to examine changes over time, but

limited the final sample size. Validation of our findings through replicating our study in other fields, with adequate sample sizes, will be necessary to consider generalizing these findings to other TDR projects. A post-project follow up study to measure changes at year five would also be beneficial to evaluate any variation in the rate or direction of change for the identified measures.

To further examine the role of graduate student in a large TDR project, it may be beneficial to conduct a qualitative study to explore their perspectives and extract details that can be difficult to capture using survey instruments exclusively.

In closing, TDR projects have shown promise in the scientific field as a method to provide an effective framework for pooling essential human and organizational resources to combat the complex scientific problems of today, but many questions still remain. How do project leaders maximize the cooperation and feedback from all parties involved? How do project developers recruit effective leaders? As we continue to examine the role of TDR as a reliable scientific method, these and other questions must be evaluated to ensure the long-term sustainability of collaborative science. Transdisciplinary science must successfully integrate and navigate the organizational challenges of creating a geographically dispersed team, with the individuals need to interact and form professional bonds with team members. Identifying and recruiting effective leaders who can integrate, collaborate, and adapt to evolving project dimensions will be essential to successful outcomes at the project level, and to provide evidence of positive impacts at the scientific level.