Learning inquiry and the nature of science through undergraduate research: Mentoring matters.

Research Based Undergraduate Science Teaching Conference II
May 21-May 23, University of Alabama, Tuscaloosa

The Problem - Undergraduate science education reform:

- **inquiry-based** teaching and learning
- deep understanding of the **nature of the scientific enterprise**
- authentic experiences that reach into the **real world** of scientific careers
- provide learning experiences that are **interdisciplinary** and that reflect what is on the **cutting edge** of both scientific and educational research (PKAL, 2006)

Undergraduate research as a context for science learning:

- Practical experience with aspects of inquiry and research skills
- Understandings about nature of scientific knowledge (NOS), and practice (NOSI)
- Subject matter knowledge

Existing Research on Benefits of UREs:

Strong empirical support for:

- **Recruitment** and **retention** of the talented and interested, minorities and women (NSF, 1990; Seymour *et al.,* 2004; Bauer & Bennett, 2003; Lopatto, 2004, 2007; Russell 2005a, 2005b, 2006; Hancock & Russell, 2008).
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Some empirical support for:

- practice of **simple research skills, critical thinking** and **epistemological development** (Kardash, 2000 ; Bauer & Bennett, 2008; Rauckhorst, Czaja & Baxter Magolda, 2001)

Scant empirical support for:

- gains in understanding **aspects of NOS & NOSI** (Ryder, Leach & Driver, 1999)

What we don’t know:

What is the potential for UREs to address reform?

- Inquiry
- NOS and NOSI

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- Inquiry
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What do these research experiences look like? **What do students and mentors actually do?**

- In what ways are students using/building inquiry and research skills and understandings?
- In what ways are students supported in learning?

Research Questions

Descriptive questions about gains:

What do students learn … through participation in this program of undergraduate research?

Q1. about the practice of scientific inquiry
Q2. about NOS and NOSI

Research Questions

Explanatory questions:

How can we explain gains (or lack of gains)?

Q3. Are there interactions among the above?

Q4. What attributes of the program might be relevant?

- Nature of the research project?
- Nature of the intern-mentor interaction?

Methods: Context

- NSF-supported paid internship in cutting edge molecular/genetics research in world-class laboratories
- 10-week summer immersion program for undergraduates
- Formal and informal interactions: seminars, lab meetings, writing assignments, symposium, social events, communal living

- Each laboratory setting is unique: a variety of inquiry experiences predetermined by the mentor, focus on technical skills

Methods: Participants

Summer 2009 Intern Cohort

- 24 students, 14 females
- 5 underrepresented minority students
- Avg. GPA = 3.7
- 4 rising Sos., 5 Jrs., 14 Srs., 1 recent graduate
- 15/24 have some prior UG research

Methods: Participants

Their Mentors

- 2 faculty members (PIs), 14 Post Docs, 1 laboratory technician (MS), 7 grad students
- 9 females, 15 males
- 12 different countries (8 US)
- Wide variety of research foci: Molecular and cyto-genetics, transgenic crops, intracelular communication, development, plant pathology, environmental responses, molecular evolution, transposon mediated mutagenesis, mycorrhizal symbioses, plant-insect interactions, gene regulation

Methods: Design

Mixed Methods:

- **Pre-Post Assessments** to investigate gains and relationships
- **Exploratory investigation** of what is happening

Data Source	1 Wk Pre	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8	Wk 9	Wk 10	1-10 Wks Post
Application Materials	●—●											
Pre-Program Questionnaire	●—●											
Early Interviews		●—	—●									
Research Proposals			●									
Longitudinal Observations				●	—	—	—	—	●			
Late Interviews										●—	—●	
Research Presentations											●	
Mentor Interviews												●— —●

Descriptive Questions about Pre-Post Gains

Q1: Gains in Inquiry Practice?
Likert Survey of Inquiry and Autonomy

In your past experiences as a science student, how often have you been able to do each of the following independently?	**(Please circle one)**				
a. Pose your own question to test, and then test it.	Never (0)	Once/Twice (1)	Sometimes (2)	Often (3)	Very Often (4)
b. Select/design the methods for a scientific investigation.	Never (0)	Once/Twice (1)	Sometimes (2)	Often (3)	Very Often (4)
c. Determine what evidence to collect, and then collect it.	Never (0)	Once/Twice (1)	Sometimes (2)	Often (3)	Very Often (4)
d. Decide how to summarize collected evidence (in a graph, figure or table, or statistically).	Never (0)	Once/Twice (1)	Sometimes (2)	Often (3)	Very Often (4)
e. Formulate an explanation for the evidence (data analysis interpretation).	Never (0)	Once/Twice (1)	Sometimes (2)	Often (3)	Very Often (4)
f. Form connections between your explanations and existing scientific knowledge.	Never (0)	Once/Twice (1)	Sometimes (2)	Often (3)	Very Often (4)

Q1: Gains in Inquiry Practice?

Pre-program INDEPENDENT inquiry

Most Common Pre:

- **1° literature**
- **Summarize evidence**
- **Explanation**
- **Connect to SK**
- **Trouble-shoot**
- **Develop argument**
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INDEPENDENT vs. GUIDED Program inquiry

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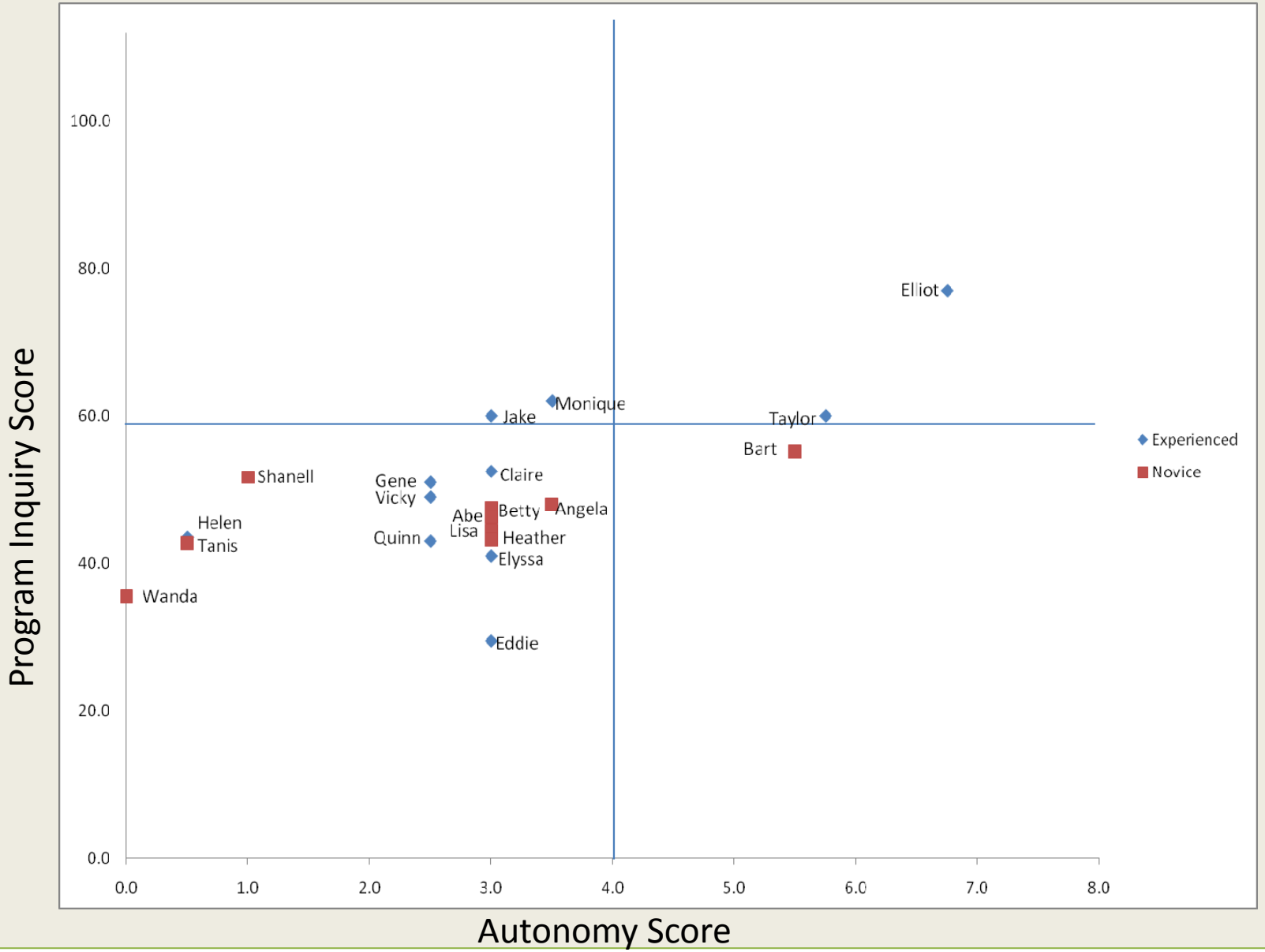
Inquiry Practice vs. Autonomy



Q2: Gains in understandings of NOS/NOSI?

Tenets of NOS

(VNOS, Lederman et al., 2002)

- Empirically based
- Theory-laden
- Tentative
- Product of human inference and creativity
- Socially and culturally embedded
- Distinction between observations and inferences
- Distinction between scientific theories and laws
- No single "Scientific Method"

Tenets of NOSI

(VOSI, Schwartz, 2004)

- Guided by questions
- Multiple purposes/reasons
- Role of anomalous data
- Role of justification and argument
- Community of practice
- Distinction between data and evidence
- No single "Scientific Method"

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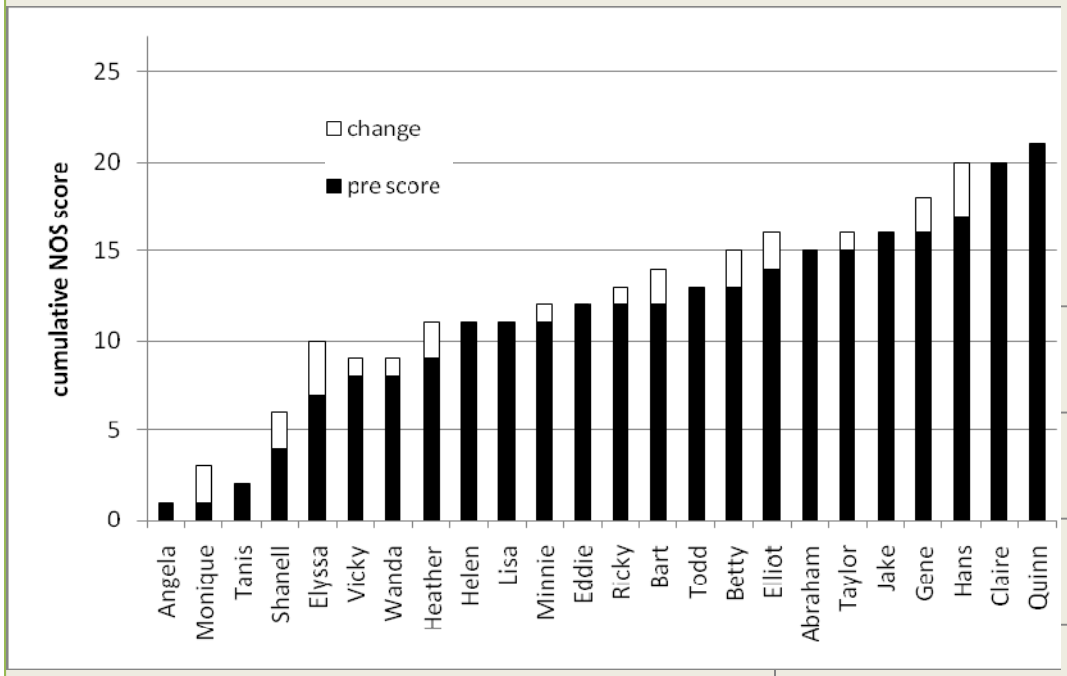

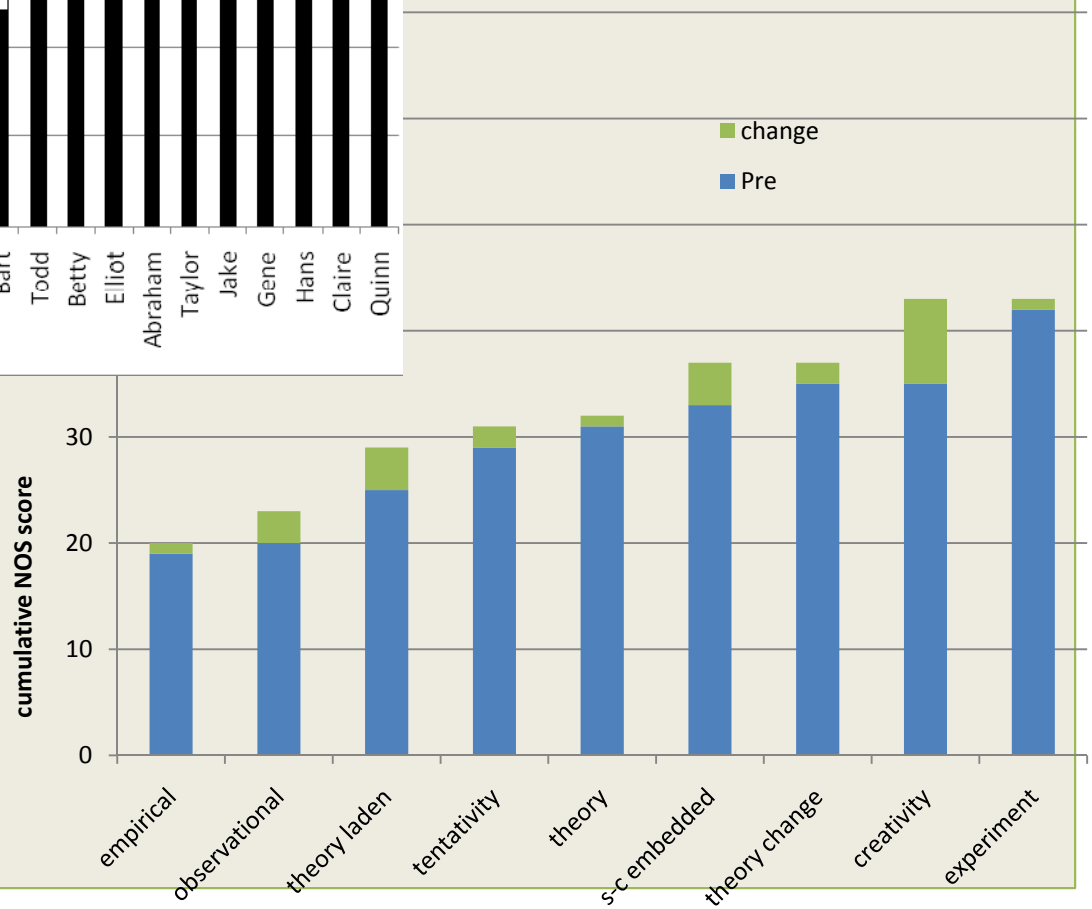

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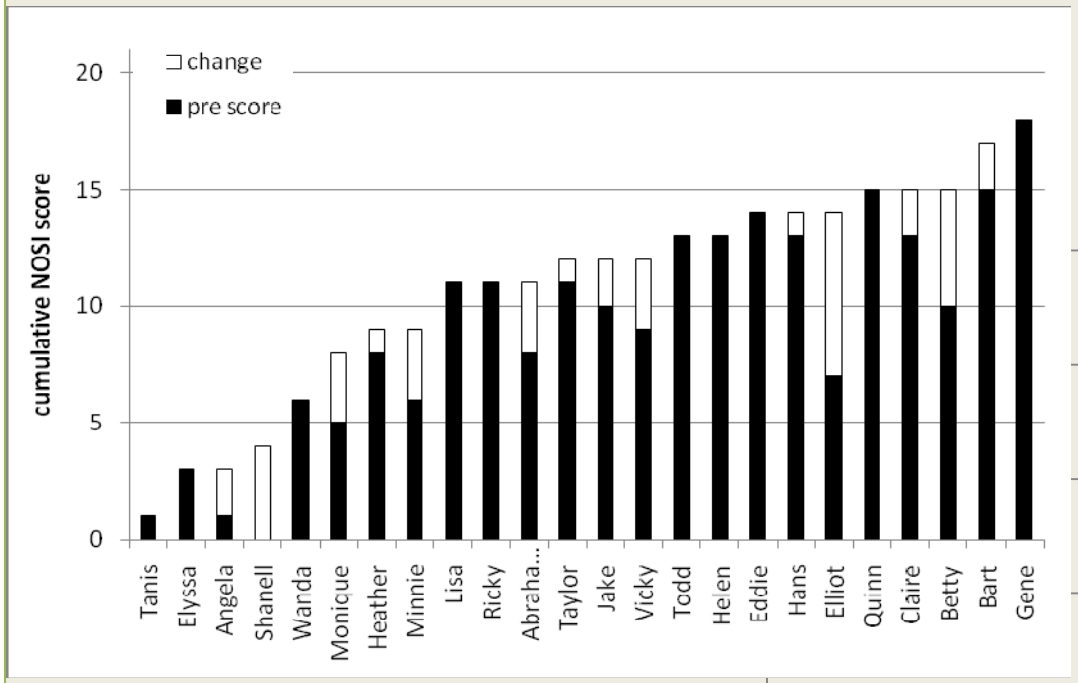

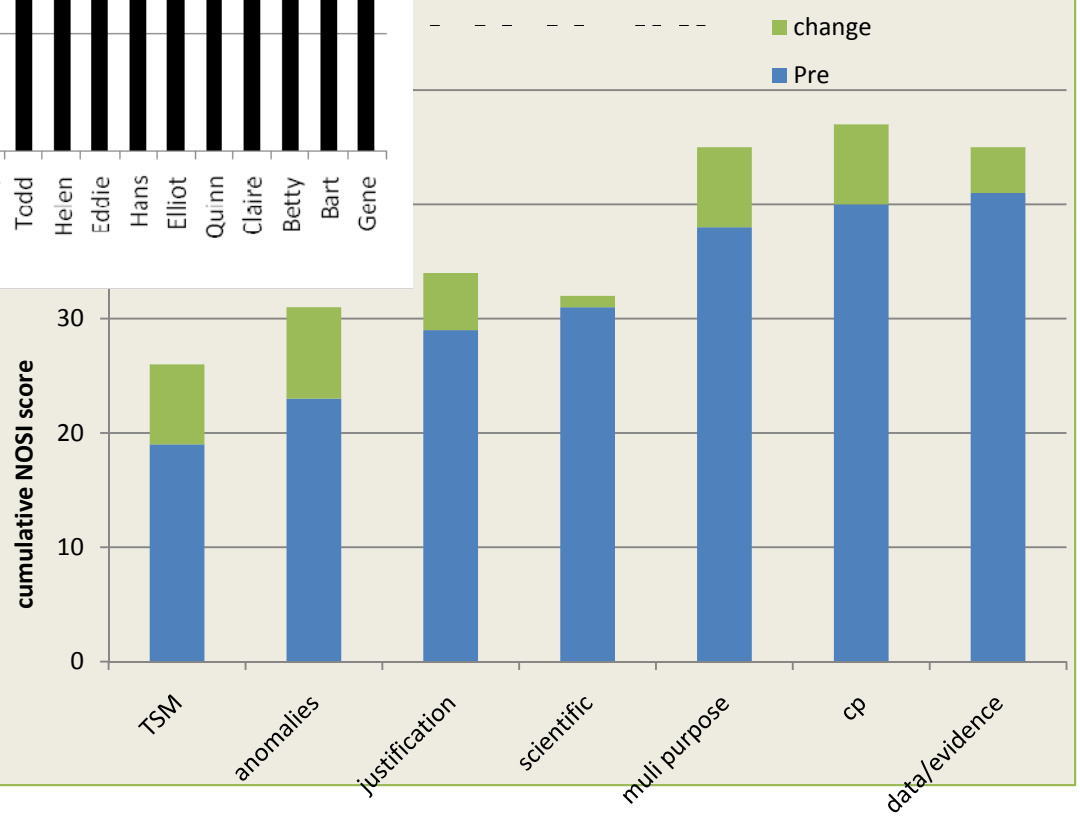

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- Independent practice of inquiry: the simpler, more common skills
- Aspects of NOS – modest change, especially creative NOS
- Aspects of NOSI – modest to moderate change, TSM, anomalies, justification, multiple purposes, community of practice

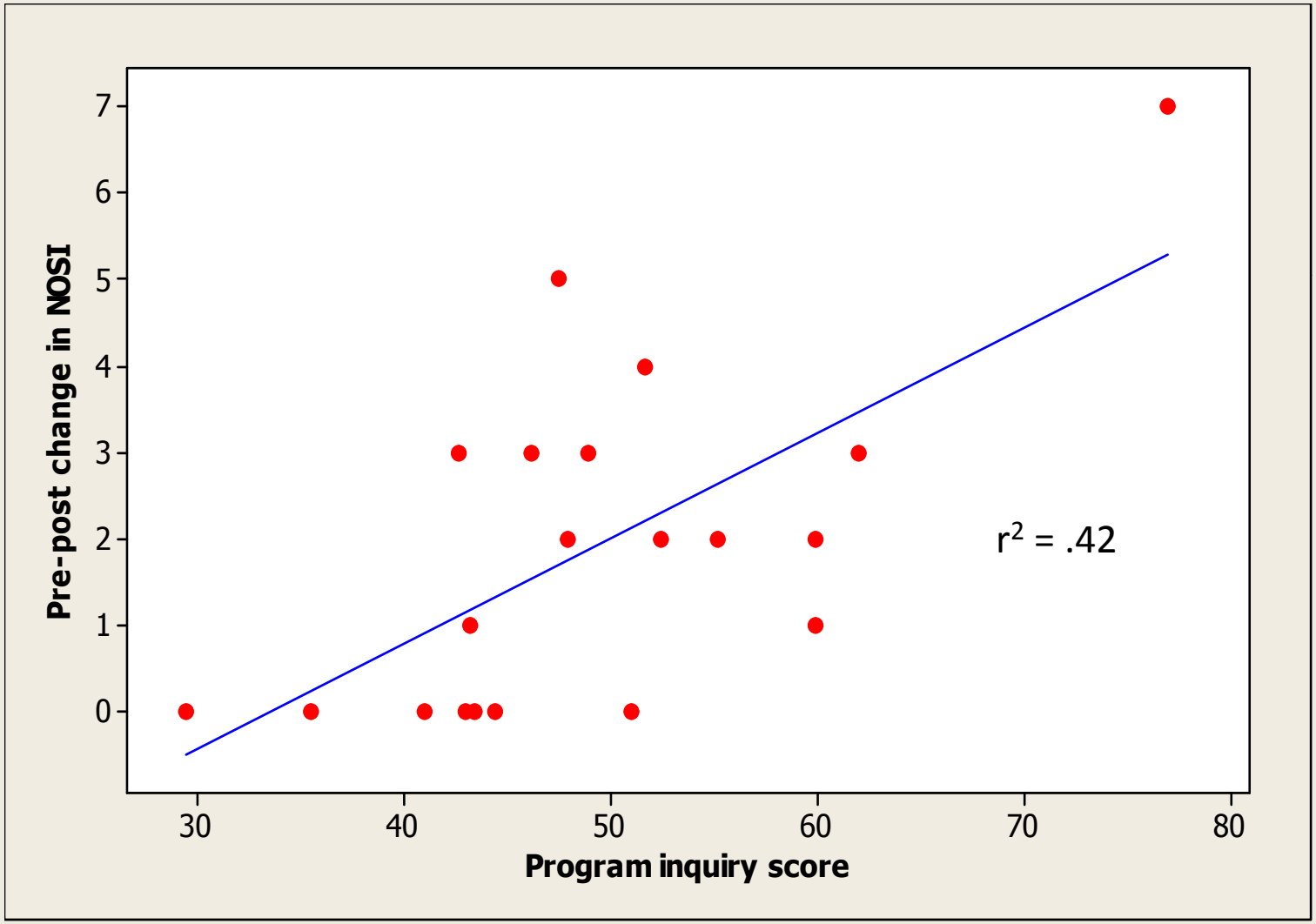
Explanatory Questions: How can we explain gains or lack of gains in the above?

Q3: Relationships among Inquiry, NOS &NOSI?

Correlations Between Program Inquiry and Post-program NOS and NOSI (n=20).

Independent variable	**Dependent variable**	***F***	**P**
Program Inquiry	Post NOS	0.58	0.455
	Change in NOS	1.42	0.249
Program Inquiry	Post NOSI	1.03	0.324
	Change in NOSI	**13.26**	**0.002**

Q3: Relationships among Inquiry, NOS &NOSI?



Q4: Program attributes?

Research Project Categories and Subcategories

Project Type		Number
Non-investigation **(NI)**	Genetic screen	4
	Tool development	2
Investigation	Observational	
	Simple **(SOI)**	3
	Multifaceted **(MOI)**	9
	Hypothesis testing **(HT)**	6

Q4: Program attributes?

Intern-Mentor Transactions

Mentor-Centric (8)			Balanced (12)			Intern-Centric (4)		
Intern/mentor pair	Project Type	Outcomes[1]	Intern/Mentor Pair	Project Type	Outcomes	Intern/Mentor Pair	Project Type	Outcomes
Wanda/Jinsong	NI	-/-	**Bart/Tim**	NI	+/+	**Shanell** (URM)/Nancy	NI	+/-
Vicky/**Ajay**	NI	-/+	Todd/**Guy**	NI	+/-	**Angela** (URM)/Young	MOI	+/+
Heather/Priya	NI	-/-	**Lisa/Midori**	MOI	+/+	Elliot/**Mandy**	MOI-HT	+/+
Eddie/**Marisol**	SOI	-/+	Quinn/**Bernard**	MOI	+/+	Monique(URM)/Christiaan	HT	+/-
Tanis(URM)[2]/**Arthur**	SOI	-/-	Taylor/Faith	MOI	+/+			
Claire/**Dick**	SOI	-/+	Hans/**Pierre**	MOI	+/+			
Ricky/Qiao	MOI	+/+	Elyssa(URM)/Selena	MOI	+/+			
Helen/Franck	HT	+/+	Gene/Xiang	MOI	+/+			
			Minnie/Grant	MOI	+/+			
			Betty/Gabriella	HT	+/+			
			Abraham/Lijuan	HT	+/+			
			Jake/Harry	HT	+/+			

[1] (-) for the intern indicates negative outcomes outweighed the positive outcomes: limited understanding of the research project's aims or outcomes, negative feelings toward the program and/or mentor, disinclination to pursue further research experiences.
(-) for the mentor indicates the research project did not produce usable results.
[2] URM – Intern belongs to a minority group underrepresented in US science

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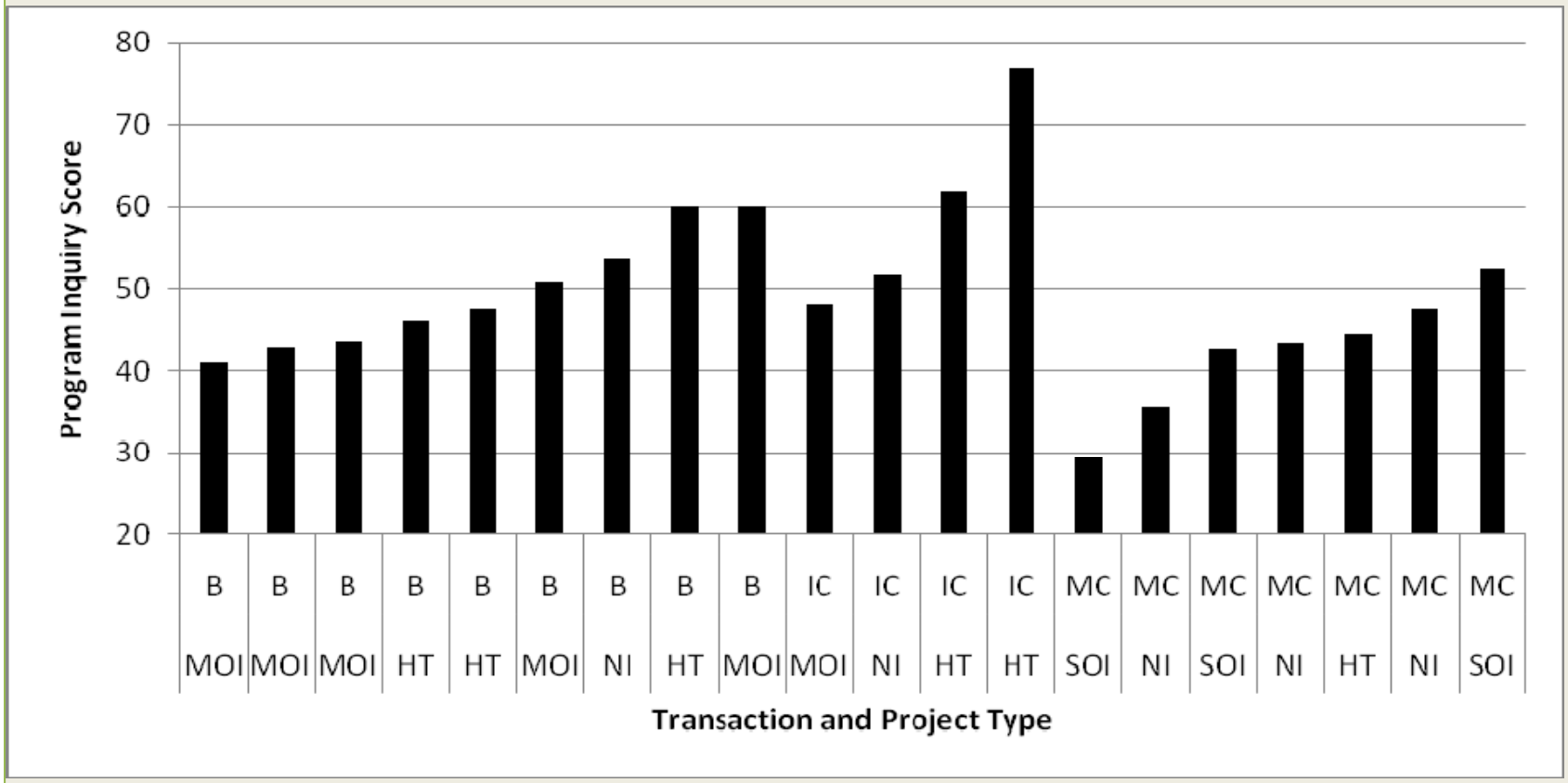

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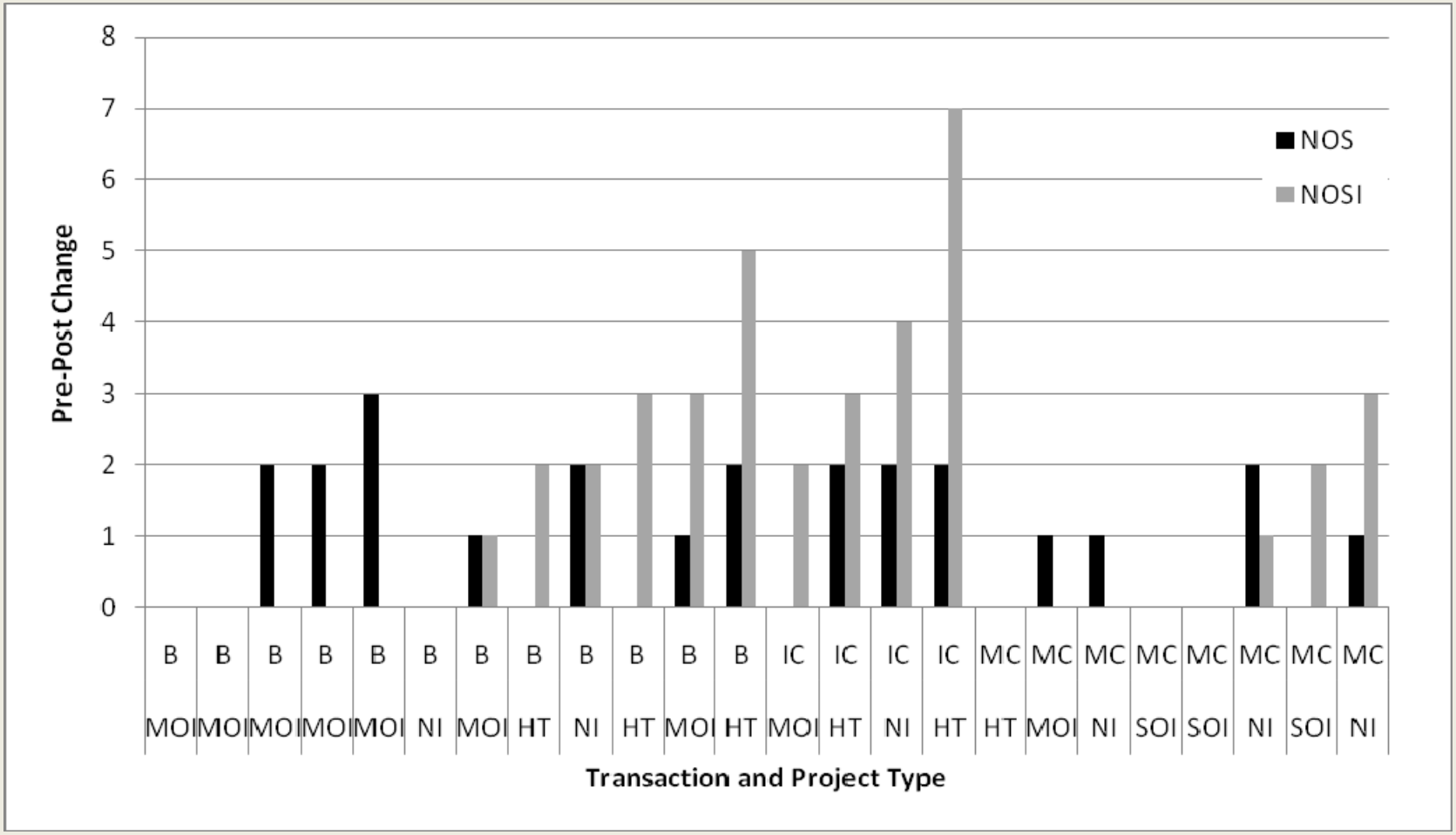

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- developing understandings about NOSI.
  - Especially HT and certain NI

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  - 2 of the 4 IC were +/-
- autonomy/independent practice of inquiry
  - More advanced inquiry
- developing understandings of NOSI
  - Particularly IC, and to some degree, B transactions

Conclusions

- UR can promote gains in practicing aspects of inquiry
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- UR can promote gains in practicing aspects of inquiry
  - But most did not independently practice the advanced stuff
  - the cutting edge context may have been a barrier
- UR can also lead to gains in understandings about NOS and NOSI
  - But does not guarantee it (also no explicit instruction)
  - Links between autonomy, engagement with inquiry and gains in NOSI
  - No clear pattern for gains in NOS (critical events?)

Conclusions

- Project type influenced the aspects of inquiry, NOS and NOSI to which the intern was exposed.
  - MOI, HT and certain NI
  - Most (regardless of type) were necessarily heavily prescribed
- Intern-mentor transaction also influenced the aspects of inquiry, NOS and NOSI to which the intern was exposed.
  - B and IC

Implications?

↑autonomy → ↑ engagement with inquiry → ↑ NOSI

B, IC

HT, NI-TD, MOI

NOS

- Opportunities to practice more advanced inquiry (greater involvement in design & analysis)
- Mentor's attitude toward the intern: hand or apprentice?
- Intern-centric situations for interns needing substantial support