Achieving Large-scale STEM Education Improvement at a Research University

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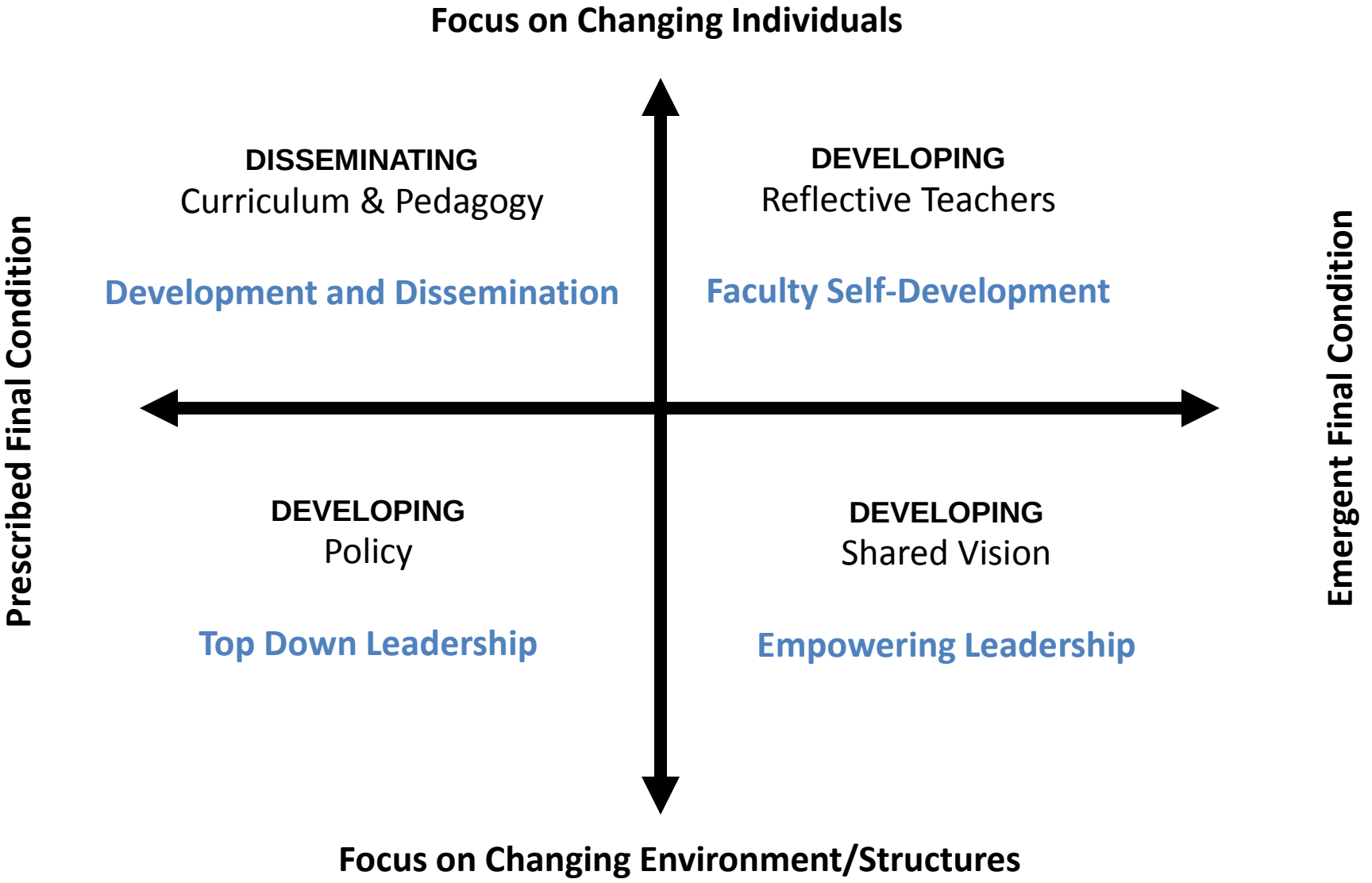
Awards: #0715698, #1022186, #0623009, #0723699

Overview

Planning for Emergent Change Using Complexity Leadership Theory

- Change strategies for institutional transformation
- Introduction to complexity leadership theory
- Application at Iowa State University
- Lessons Learned

Four Categories of Change Strategies

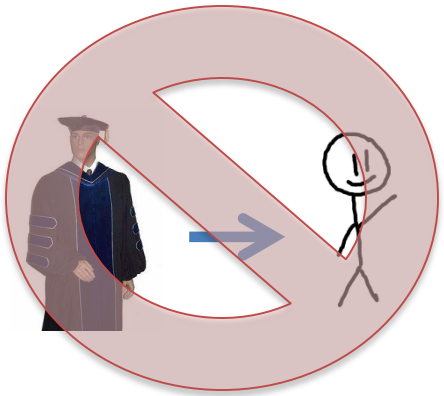


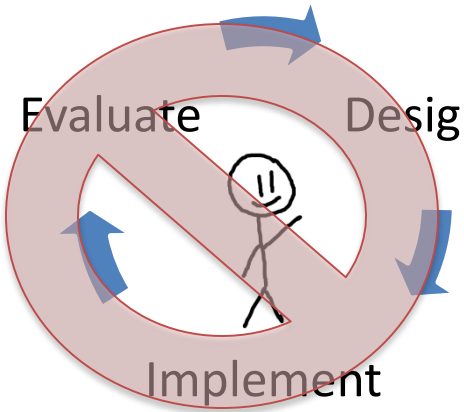
*C. Henderson, A. Beach, and N. Finkelstein, "Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching*, *48*(8), 952-984 (2011).

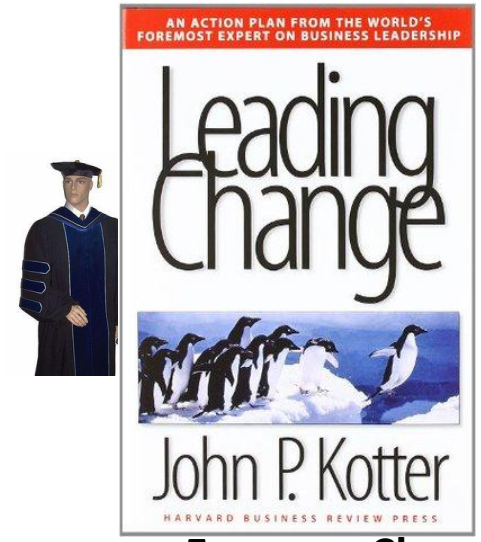
How they Work

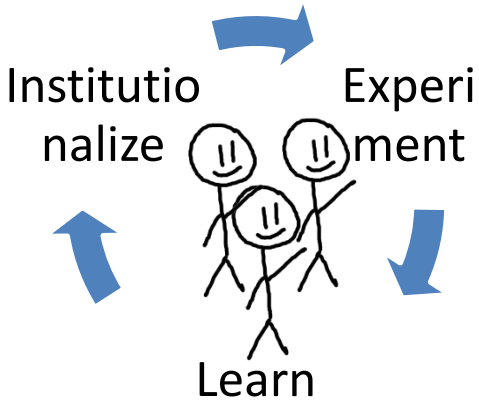
Focus on Changing Individuals

Prescribed Final Condition









Emergent Final Condition

Focus on Changing Environment/Structures

*C. Henderson, A. Beach, and N. Finkelstein, "Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching*, *48*(8), 952-984 (2011).

Complexity Leadership Theory

Change is cyclic and ongoing

Complexity Leadership Theory's Enabling Leadership (Uhl-Bien et al., 2007)
Change is cyclic and ongoing
1. Disrupting patterns to encourage interactions between individuals
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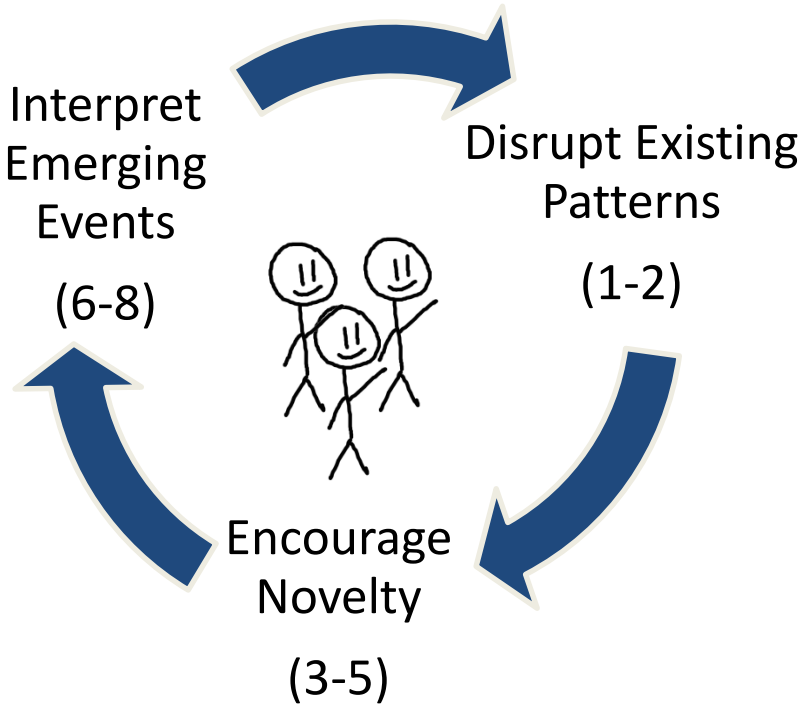
4. Avoiding stifling regulations
5. Articulating the vision
6. Identifying emerging knowledge from interactions
7. Communicating emerging knowledge to formal leadership
8. Implementing knowledge

Quardokus, K. (2014). Unpublished Doctoral Dissertation.



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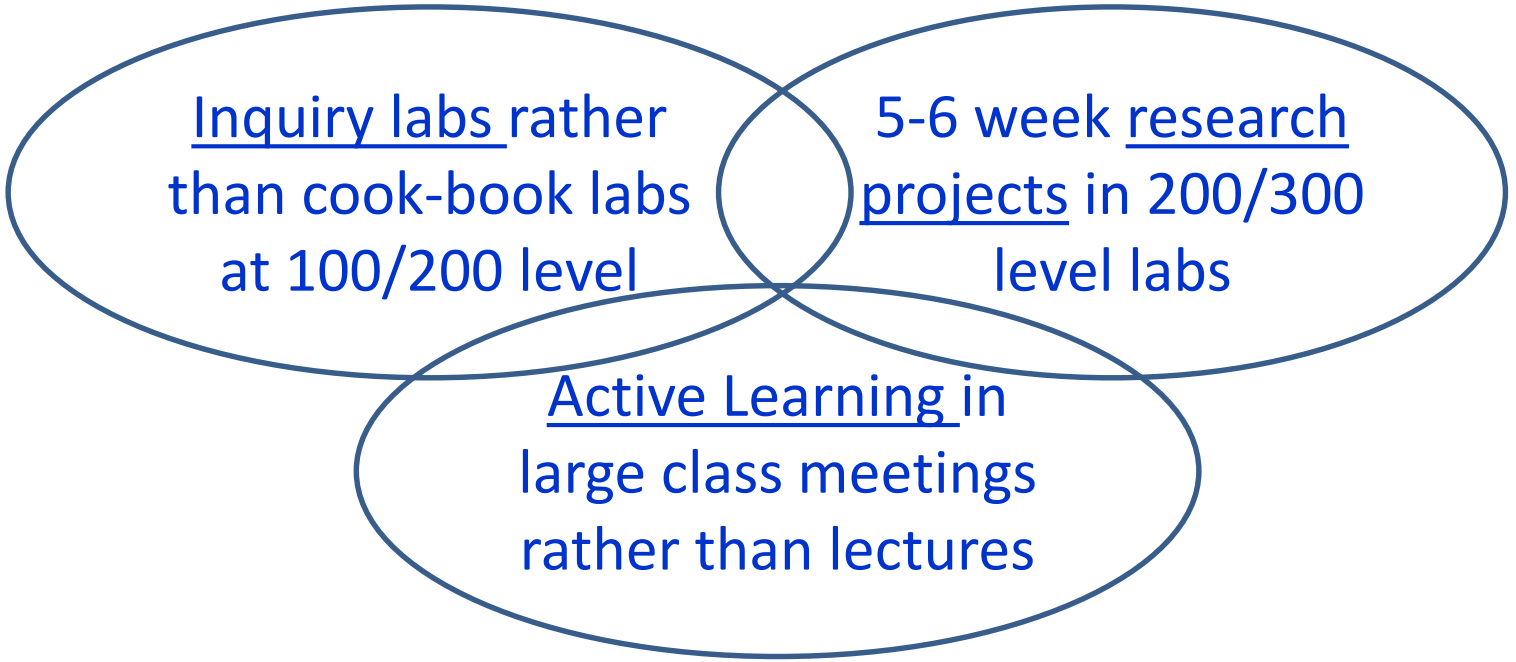
HHMI–ISU Project 2010-2014

Simple Rule: students should do science in the first two years of college



Multiple depts: biology, chemistry, physics, astronomy, geology, meteorology, psychology, math…

Emergent change enacted by Faculty Working Groups (FWGs)

- Structure of FWGs
  - 5-10 faculty who are teaching similar classes
  - Regular bi-weekly meetings
  - Led by faculty facilitators
  - Supported by a post doc (fractional time)
    - new ideas, time, urgency
- ~80 faculty and staff involved
  - Groups ranged from 1 to 3 years in duration

FWG: Changed cookbook labs to inquiry labs
(all intro physics, biology, chemistry, geology, ~10K students/year)

- E.g. Physics
  - Cookbook: measure P, V, T of gas and plot P vs V etc.
  - Inquiry: Determine if air exhibits properties of an ideal gas.

Class as a scientific community

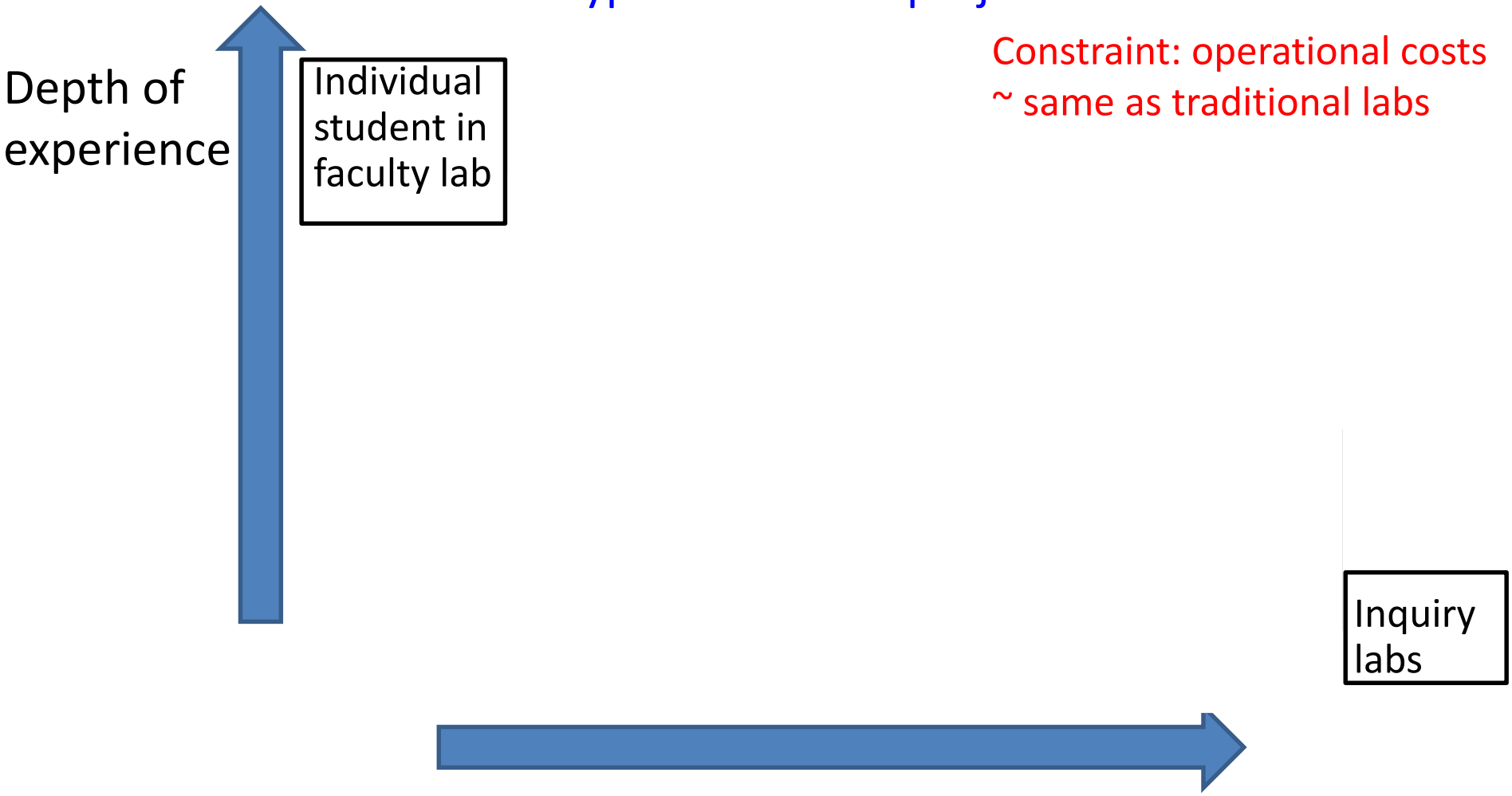
- Discuss strategies at start of lab
- Pool results at end

Adapted from POGIL, Science Writing Heuristic

How to get more students engaged in research?

FWG: Different types of 5-week projects in lab courses

Constraint: operational costs
~ same as traditional labs



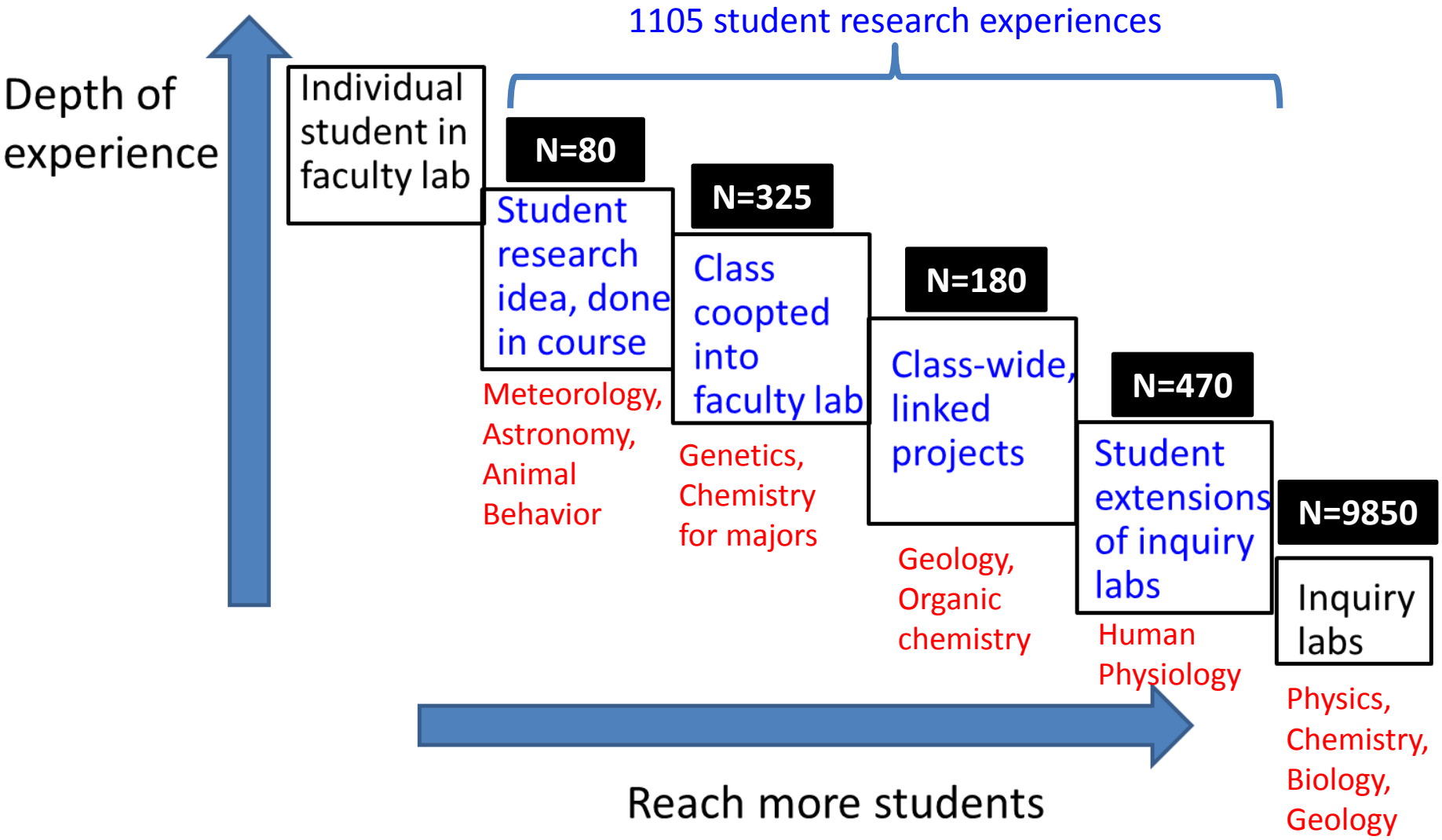
Research-lab FWG: 3 years

- Planning of course-based 5-week research projects
  - Typology, scale, scope of student research projects
  - Explicit attention and assessment of Nature of Science
- Support during first implementation
- Recent refinements
  - Use inquiry labs to build towards research project
  - Spinoff of TA Learning Community
  - Added citizen science, freshmen projects

Example: Whole class coopted into faculty lab

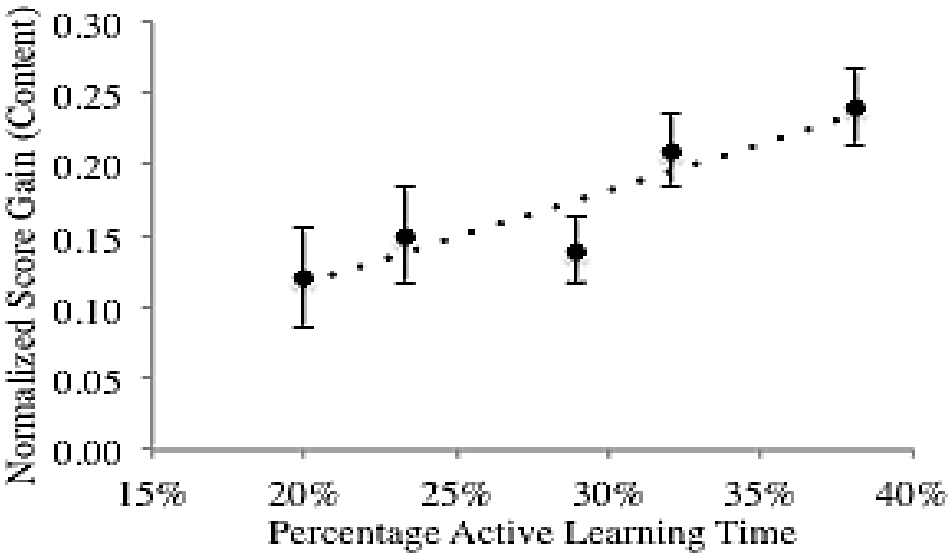
- Genetics (325 students)
  - Students unofficially joined the NSF Engineering Research Center for Biorenewable Chemicals (CBIRC)
    - Biorenewable feedstock to replace petroleum-based products.
  - Can we engineer model organisms (yeast) to make more fat?
  - Each group of students designed an experimental investigation to compare fatty acid production of their strain of yeast compared with a parental strain.
    - Promising results sent to CBIRC for follow-up

More students engaged in research



FWG: Adding active leaning into intro biology

- FWG worked to develop, share, implement clicker questions and case discussions
- Multiple sections, different faculty implementations

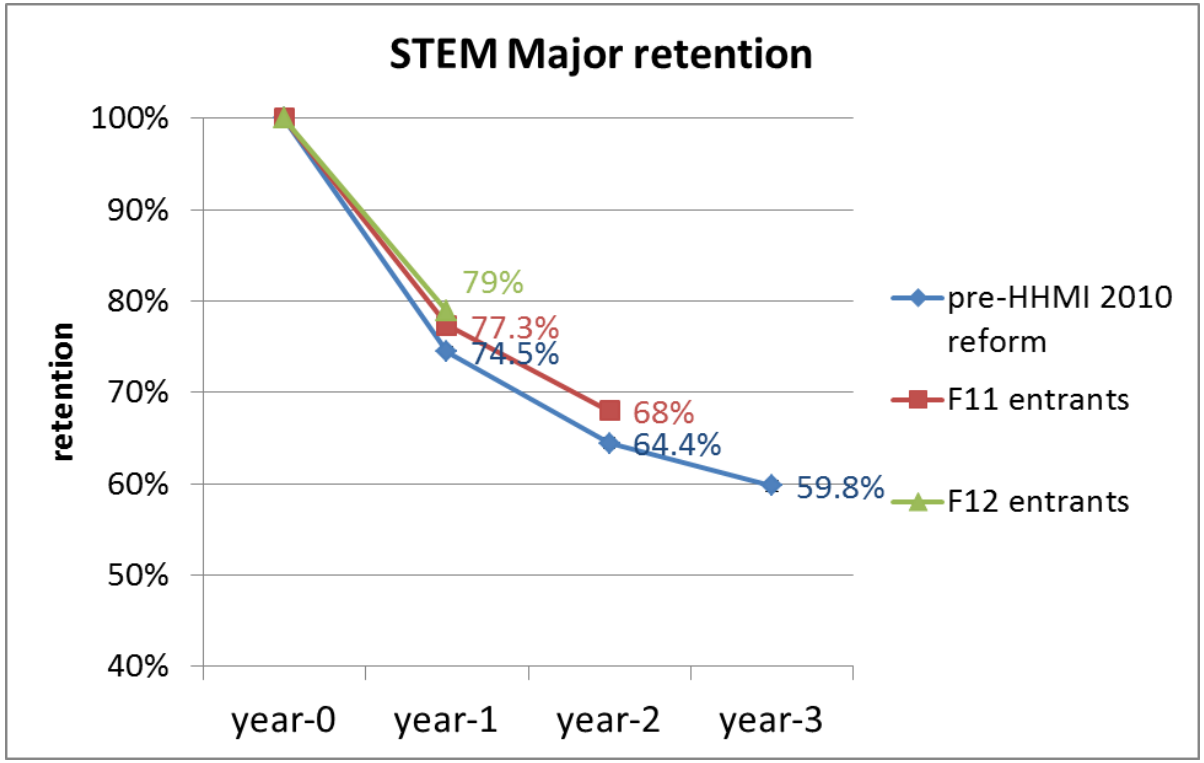


Student learning increases with the amount of faculty use of active learning

E.R. Elliot et al, submitted for publication

Note, other FWGs for large lectures did not implement changes

These changes have improved retention of STEM majors at ISU



Uptick post reform, hard to prove cause

Kept 4% additional students of prior 25% freshmen loss, changed 1 in 6 students' decision

Successes and Failures from a Complexity Leadership Theory Perspective

Complexity Leadership Theory's Enabling Leadership (Uhl-Bien et al., 2007)
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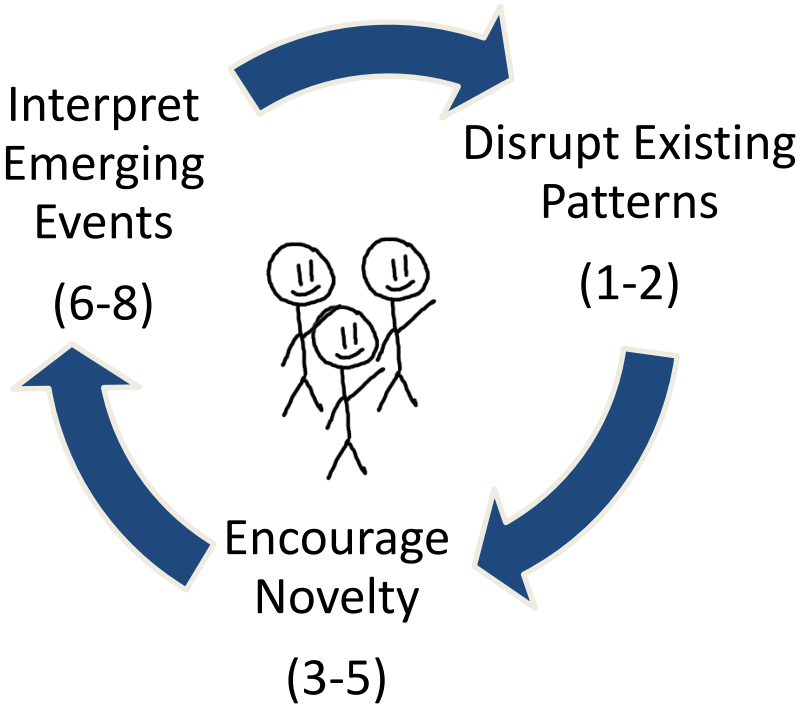

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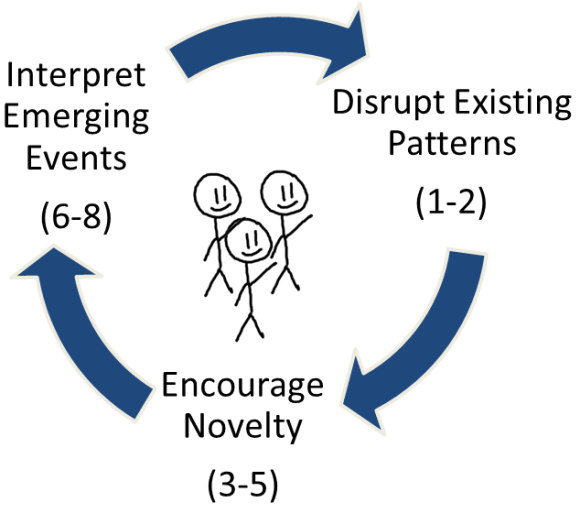
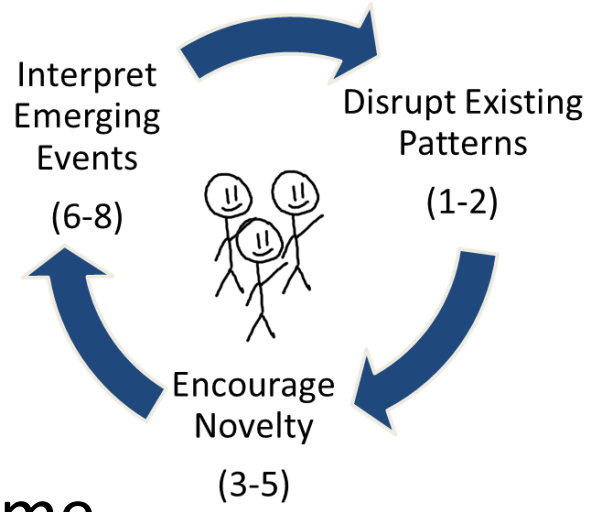
Disrupt Existing Patterns



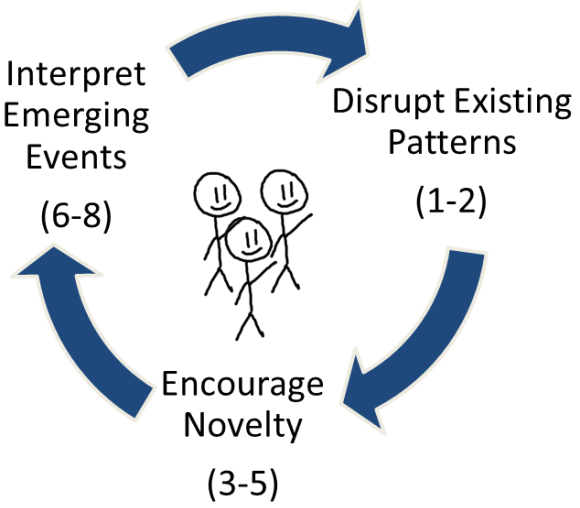
- **Successes**
  - Creation of Faculty Working Groups
  - Post doc to support FWGs: new ideas, time, urgency
  - Creation of Graduate TA Learning Communities
- **Failures**
  - 2 Lecture-focused FWGs were ineffective
    - Simple Message of "students should do science in the first two years of college" did not match with the goals of these faculty
    - Not sufficient interdependence in groups

Encourage Novelty



- Successes
  - **Moderate Diversity**: Groups have some diversity of ideas/experiences, but not so much that it is a barrier
  - **Simple rule**: Work framed by compelling, simple rule or question (e.g., "students should do science in their first two years")
  - **Support:** The FWGs provided a mechanism for early adopters to mutually support each other during implementation bumps.

Interpret Emerging Events



- **Successes**
  - In successful department: supportive department chair (personal interactions, time in faculty meetings)
  - Post doc played an important role
- **Failures**
  - FWG activities not consistently connected with existing management structures in the departments
  - Project activities did not result in shared language that spread to others

Two Additional Examples

- CU Boulder (Wieman Course Transformation Model)
- U of Maryland College Park (Marbach-Ad Research Group Model)

Wieman Course Transformation Model

Course Level → Program Level

- **Disrupt existing patterns**
  - Focus on upper-division E&M course. 13 instructors met 7 times to set goals. Significant support by post doc.
  - Developed an assessment instrument
- **Encourage Novelty**
  - Core Question: "What is junior E&M1 about? How is it different from the introductory E&M course?"
- **Interpret Emerging Events**
  - Significant "behind the scenes" work by post docs and others to synthesize ideas and report back to larger group
  - Course level led to broader program level goals (and shared language in the department)

Chasteen, S. V., Pepper, R. E., Caballero, M. D., Pollock, S. J., & Perkins, K. K. (2012). Colorado Upper-Division Electrostatics diagnostic: A conceptual assessment for the junior level. *Physical Review Special Topics - Physics Education Research*, *8*(2), 020108.

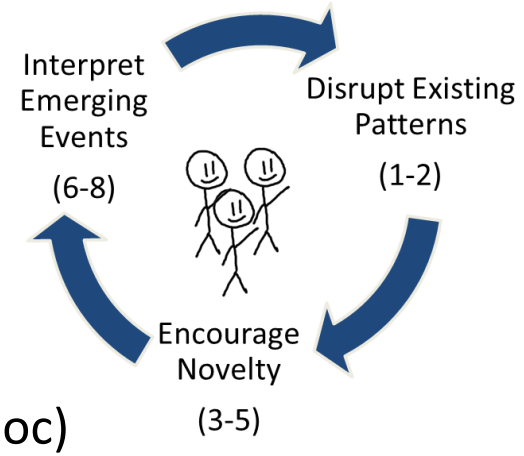
Marbach-Ad Research Group Model

Start with Important Topic Area

- **Disrupt existing patterns**
  - Focus on 7 microbiology courses, minimize overlap, allow courses to build on one another
  - 12 instructors meet monthly. Supported by a graduate student.
  - Develop assessment instrument
- **Encourage Novelty**
  - Core Question: "What do we want our students to truly understand and remember 5 years afterwards?"
- **Interpret Emerging Events**
  - Instructors change courses and discuss experiences with group.
  - Assessment results help to guide discussion.
  - (Spread did not occur)

- Marbach-Ad, G., McAdams, K. C., Benson, S., Briken, V., Cathcart, L., Chase, M., … Smith, A. C. (2010). A model for using a concept inventory as a tool for students' assessment and faculty professional development. *CBE Life Sciences Education*, *9*(4), 408–16. doi:10.1187/cbe.10-05-0069
- Marbach-Ad, G., Briken, V., Frauwirth, K., Gao, L.-Y., Hutcheson, S. W., Joseph, S. W., … Smith, A. C. (2007). A faculty team works to create content linkages among various courses to increase meaningful learning of targeted concepts of microbiology. *CBE Life Sciences Education*, *6*(2), 155–62. doi:10.1187/cbe.06-12-0212

Lessons Learned: Planning for Emergent Change Using Complexity Leadership Theory



Examples do well in:

- Disrupt existing patterns:
  - **Support**: Working groups need support (e.g., post doc)
  - **Interdependence**: Individuals have a reason to work together (e.g., new course assignment)
- Encourage Novelty
  - **Moderate Diversity**: Groups have some diversity of ideas/experiences, but not so much that it is a barrier
  - **Simple rule**: Work framed by compelling, simple rule or question (e.g., "students should do science in their first two years")

Less well in:

- Interpret Emerging Events
  - **Facilitation**: interpreting within groups
    - post doc or grad student played an important role
    - Additional one-on-one communication outside of group meetings
  - **Communication**: Spreading ideas outside of groups
    - Shared Language: extracting principles from details

Backup slides

Kotter's Eight Stage Change Model

Change is episodic, with a clear beginning and end

Implementing & sustaining for change

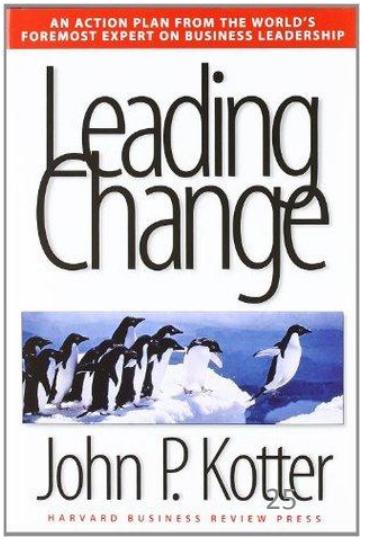
8. Make it stick
7. Build on the change

Engaging & enabling the organisation

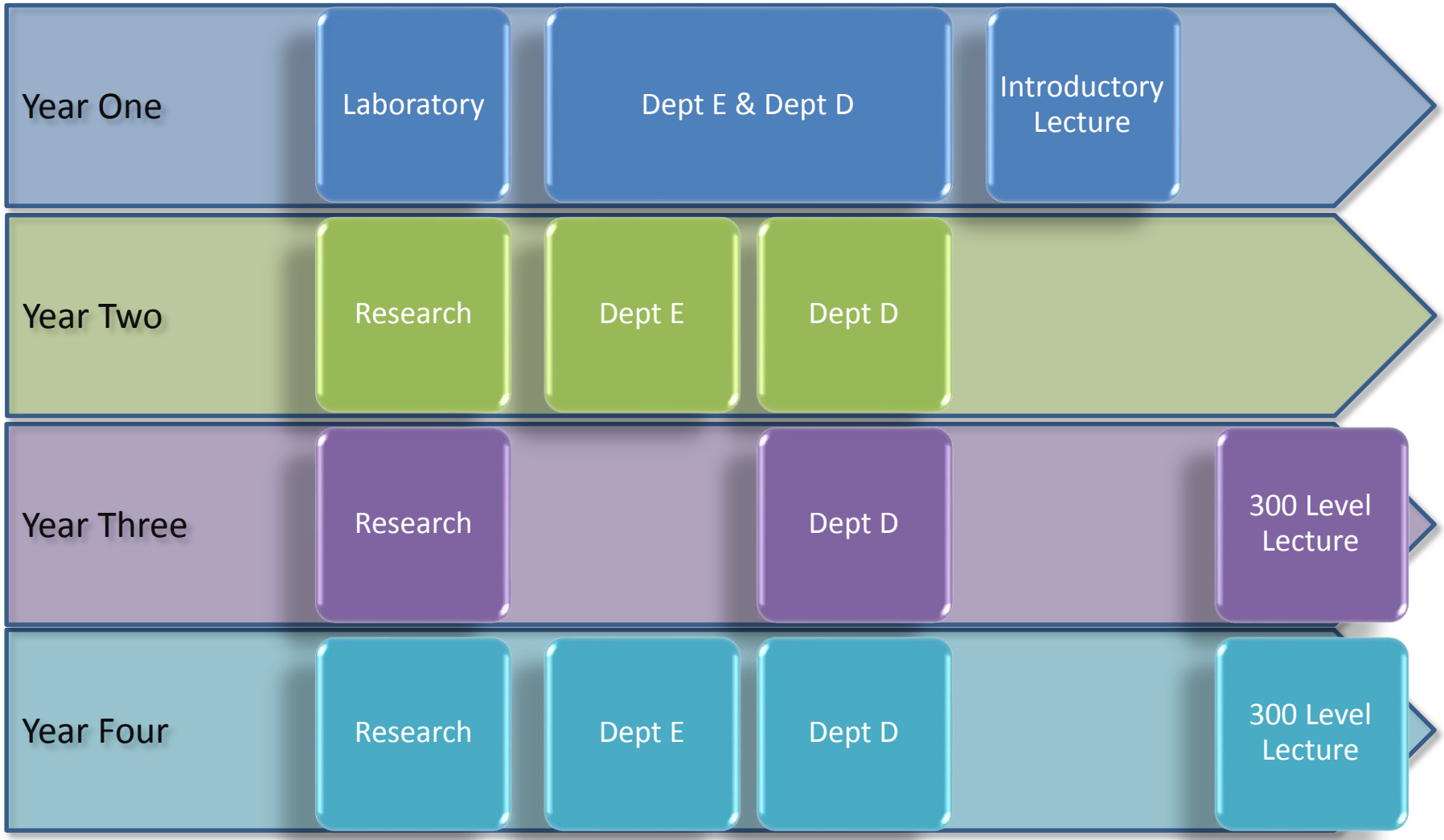
6. Create quick wins
5. Empower action
4. Communicate the vision

Creating the climate for change

3. Create a vision for change
2. Form a powerful coalition
1. Create urgency



Faculty Working Groups



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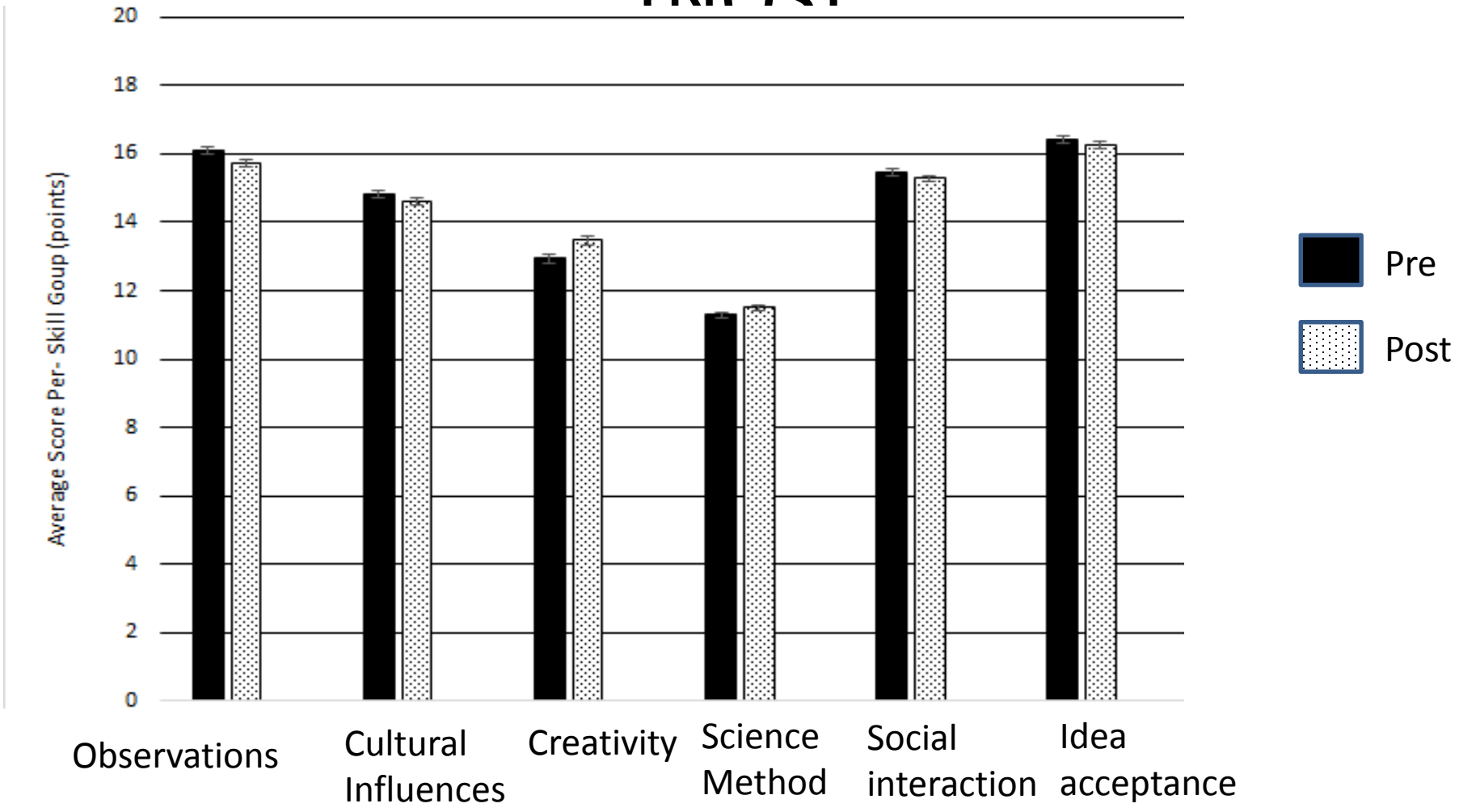
Assessment: Nature of Science (NOS)



Across all courses, no improvement, except "creativity"

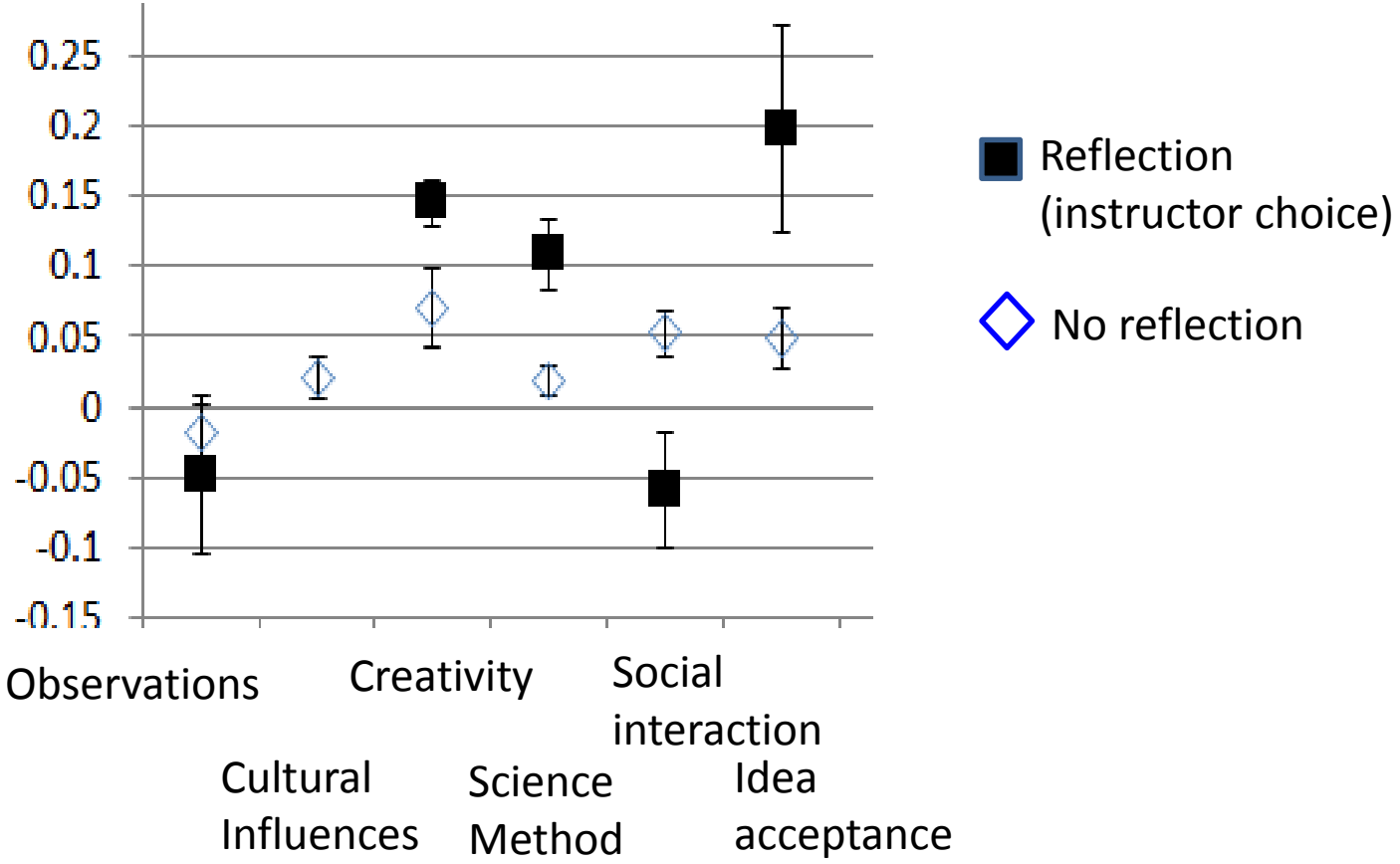
SUSSI, Liang et al, 2008

Assessment: Nature of Science (NOS)

Students asked to write/reflect on some topics of NOS

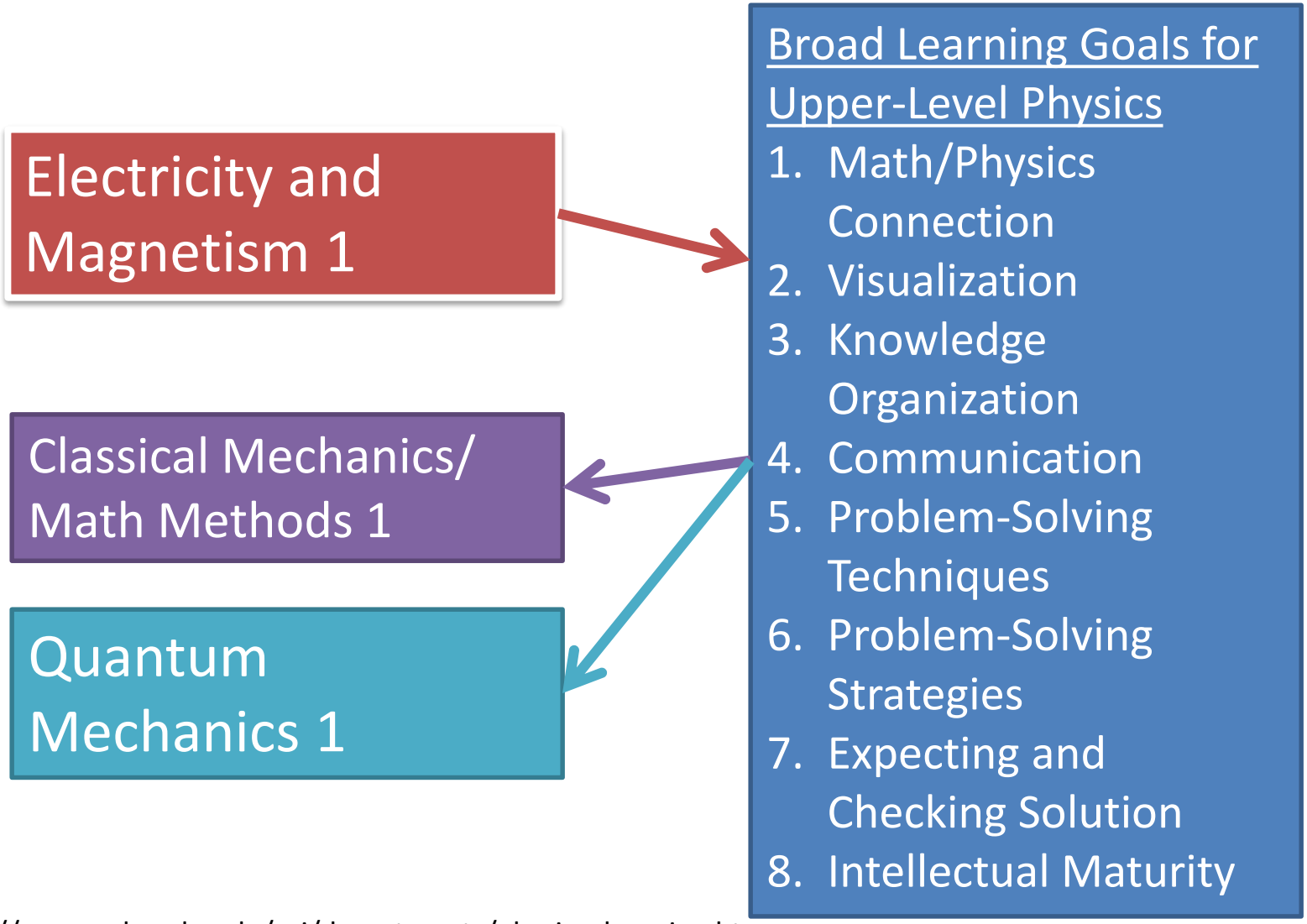
⇒moderate improvement

$$\text{gain} = \frac{Post - pre}{max - pre}$$



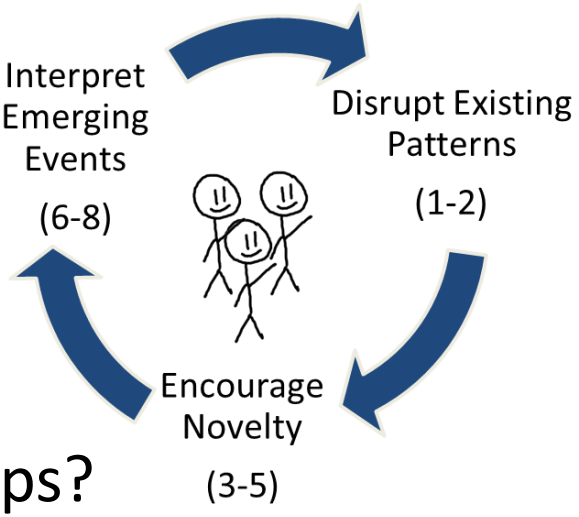
Students come to university science with NOS conceptions that are difficult to substantially alter.

Course Level Led to Broader Program Level Goals



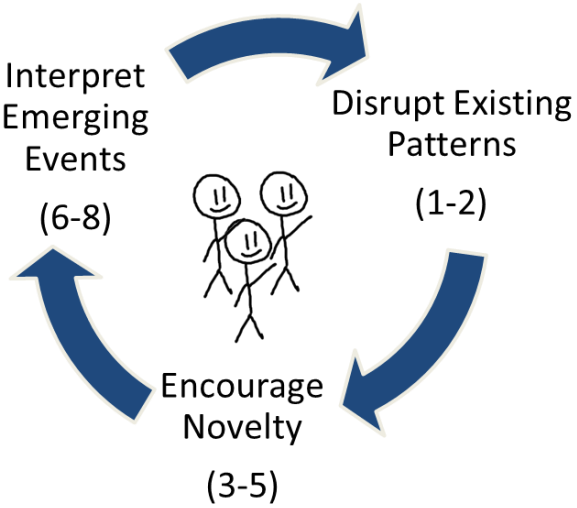
http://www.colorado.edu/sei/departments/physics_learning.htm

Planning Questions for Emergent Change within the Complexity Leadership Theory Framework



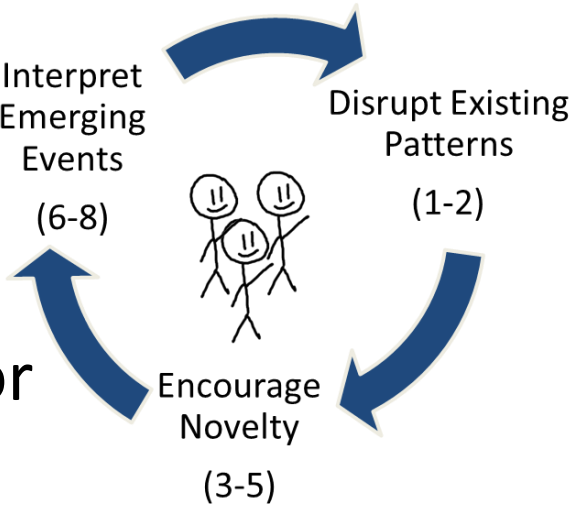
- Disrupt existing patterns
  - Structure of working groups.
    - What is the composition of these groups?
    - How many groups are there?
    - What will be their task and time frame?
    - What resources/support are available to them?
    - Why would people want to participate?

Planning Questions for Emergent Change within the Complexity Leadership Theory Framework



- Encourage Novelty
  - What is the “simple rule” to guide thinking?
  - What are the likely barriers to progress? How can these be eliminated or lowered?

Planning Questions for Emergent Change within the Complexity Leadership Theory Framework



- Interpret Emerging Events
  - Facilitation: Who will be responsible for making sure that groups are being productive? How will they do this?
  - Communication: How will productive ideas be identified, generalized, and spread outside of the group?