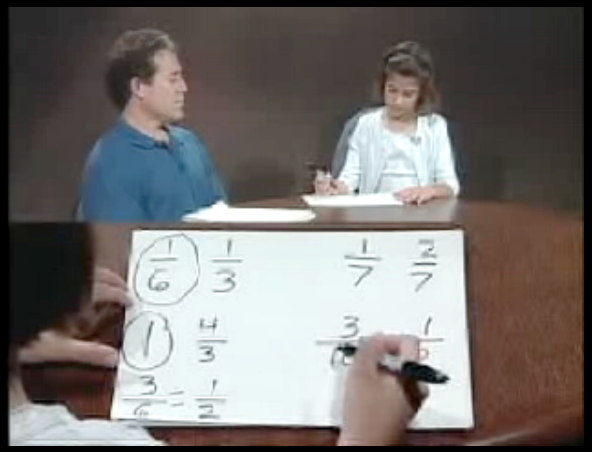
What has Ally Learned?
Outcomes for Students and Teachers of IBL Mathematics Courses



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Thanks *to the Educational Advancement Foundation (EAF)*

Overview of the project

Large, mixed-methods study of inquiry-based learning (IBL) as implemented in 4 research mathematics departments with "IBL Centers" established in 2004

1) What are the *student outcomes* of IBL mathematics courses?
   - Math learning & thinking; affective and social outcomes
2) How do these outcomes vary among *student groups*?
   - IBL vs. non-IBL courses, but also…
   - …by gender; course type; achievement level; etc.
3) By what *processes* do these outcomes arise?
   - the roles of students, instructors,TAs; classroom practices

Conceptual design of the study

2 types of courses	Math learning & thinking: *external measures*	Math learning & thinking: *student self-report*	Attitudes & beliefs	Longer-term impacts	Classroom processes
Math track (intro & advanced)	~120 "Proof tests" *	~1200 surveys of learning gains * ~800 matched pre/post surveys of attitudes & beliefs * 68 interviews with students		~3200 academic transcripts* Interviews	~300 hrs of classroom observation * 44 interviews with instructors
Teaching track (pre-service K12)	~100 LMT tests, pre/post			Interviews	

Comparison with non-IBL sections where possible*

Emphasis on "signature" IBL courses on each campus

Checkerboard of interlinked studies for triangulation

Studying real-world education reform

Inherent variety in courses & audiences

- 4 departments teaching ~30 classes
- Targeted to 1st-year students, intro to proof, math majors, pre-service K-12 teachers
- Many math topics

Varying definitions and practices of “IBL”

- Campus cultures
- Methods & levels of instructor development & mentoring vary
- Some “non-IBL” courses also use active learning

- Variety broadens the definition of what exactly is being evaluated

+ …but enables linkage of outcomes with practices along a spectrum

+ These are realistic implementations of IBL… *not* an idealized scenario

What *is* inquiry-based learning?

IBL classrooms: Instructors' aims

Get students to …

- Engage in the material
- Figure things out for themselves and therefore understand them deeply
- Explain it to somebody else and thereby make it their own
- Learn how to learn new and difficult things
- Develop confidence that your answer is right, even if someone with authority hasn't told you.

IBL classrooms: Student experiences

Deep engagement + collaboration…

I do have to work harder, but I feel like when I've finished a proof, I've actually accomplished something.

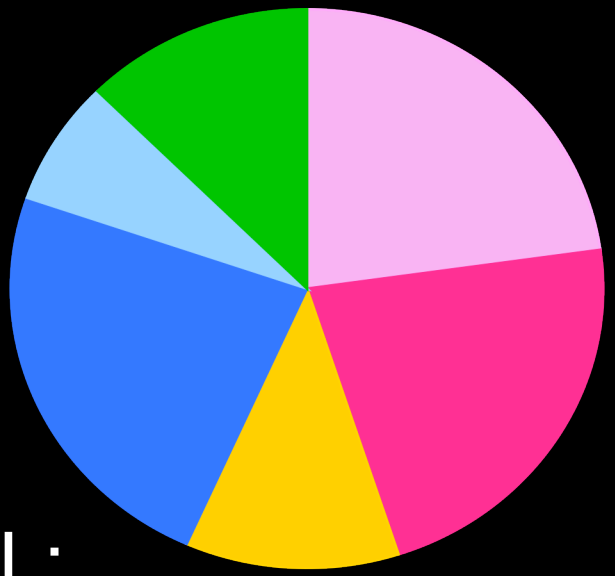
Once you spend time alone with it, then talking to other people really helps solidify it.

You can't just write the proof up on the board and expect everybody to get it—you need to really explain it. And explaining it further helps me get it too.

We have to work in the group— we can't do this alone.

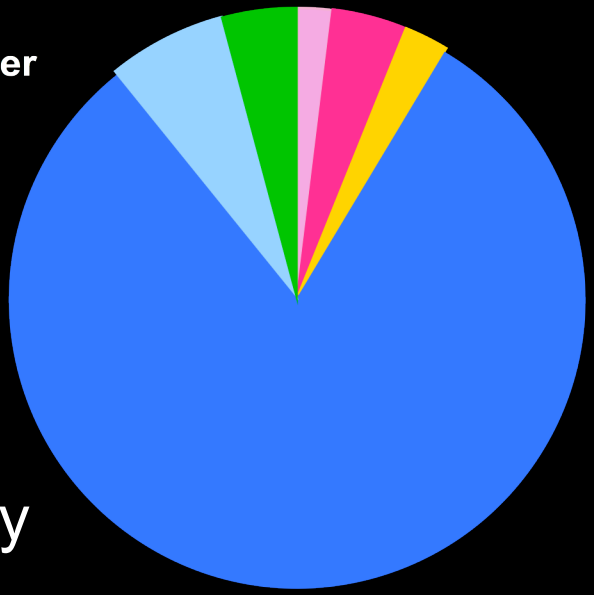
Side effects: persistence, payoff of effort, responsibility to others; communication skills, confidence, seeing multiple routes to solution

Mean instructional practices in IBL and non-IBL classrooms



Presentation
Group work
Discussion
Lecture
Explanation
Other

IBL:
Student-centered activity



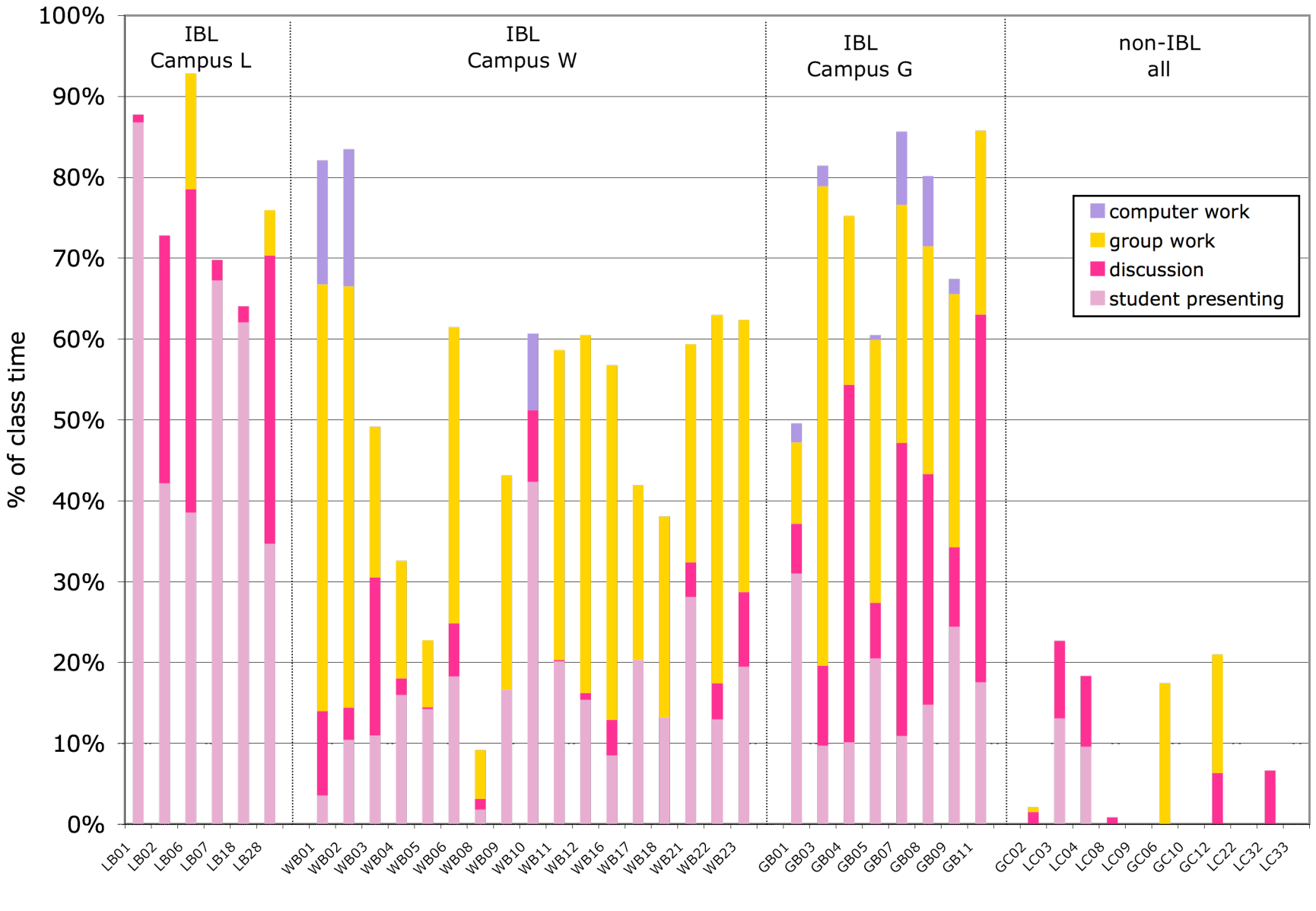
Presentation
Group work
Discussion
Lecture
Explanation
Other

Non-IBL:
Instructor-centered activity

IBL courses also differ in other ways

On average…	***IBL***	***Non-IBL***
IBL classes change gears more often	8.6 activities/hr	3.3 activities/hr
Students take the lead more often (student, group, class as a whole)	57% of class time	6% of class time
Students ask more questions, per hour	13	5
…and more students ask at least 1 question in any class period	33% of students	14% of students
Observer ratings of extent of…	(14 items total, scale 1-5)	
Student-student interactions (3 items)	3.31	1.43
Student-instructor interactions (7)	3.34	1.75
Joint responsibility for course direction (2)	2.31	0.97
Instructor sets atmosphere, summarizes (2)	3.70	3.50

Variation of instructional practices in IBL and non-IBL classrooms



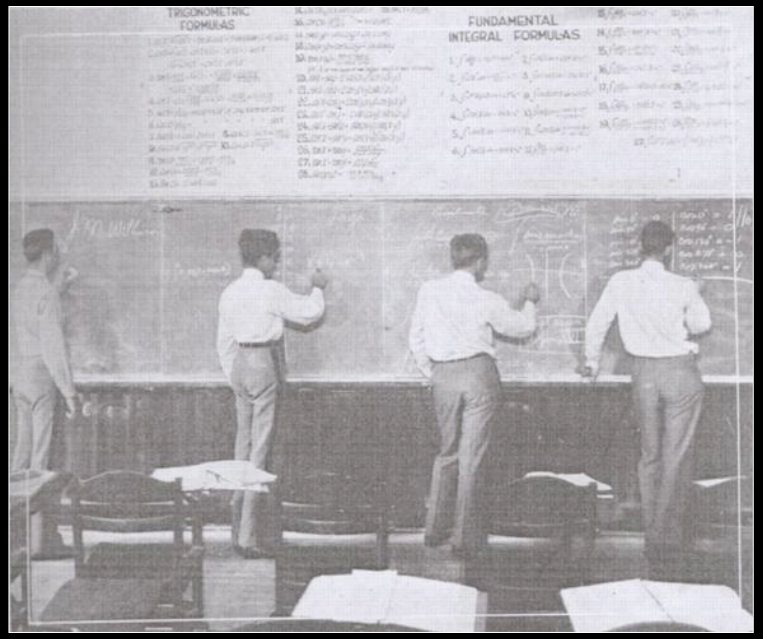
IBL classrooms: Observed activities

- Students solve challenging problems alone or in groups; share solutions; analyze, critique & refine their solutions
- Class time is used for these student-centered activities; students play a leadership role; activities change often
- Course is driven by a carefully built sequence of problems or proofs, rather than a textbook
- Pace is set by students' progress through this sequence
- Course goals usually emphasize thinking skills & communication; content "coverage" is less central
- Instructor serves as "guide on the side" not "sage on the stage"—manager, monitor, summarizer, cheerleader

What are the student outcomes of IBL instruction?

Three claims about student outcomes

1. IBL instruction has positive outcomes for students
2. Especially women
3. And students with lower levels of prior achievement



General measures of student outcomes

Learning gains: cognitive (math thinking, understanding concepts, application of math knowledge, teaching). Also affective gains.

- From post-survey (SALG-M) section, "How much did you learn…"
- Composite variables from several survey scales; range from 1-5

IBL math track	Non-IBL math track	IBL pre-service teachers
563	288	220

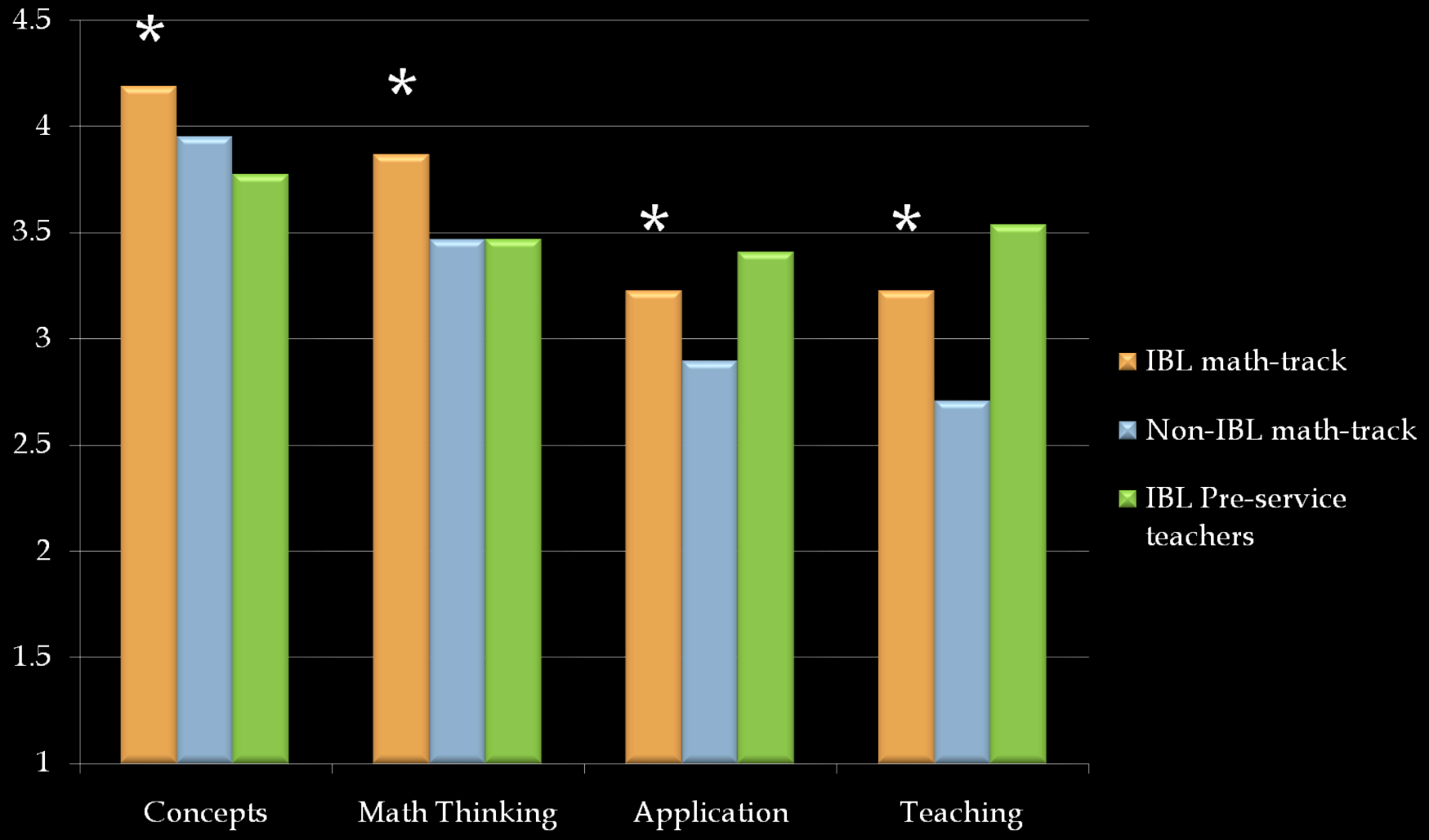
Grades: average grades from required, elective, & IBL classes taken after the target class; average target grade, next semester GPA. Also course-taking patterns, number of courses taken.

- From student academic records for one course, one university
- Constructed variables that exclude W/Q, I, CR/NC from averages
- Include grades for repeat attempts of taking a class

IBL math track	Non-IBL math track
211	1130

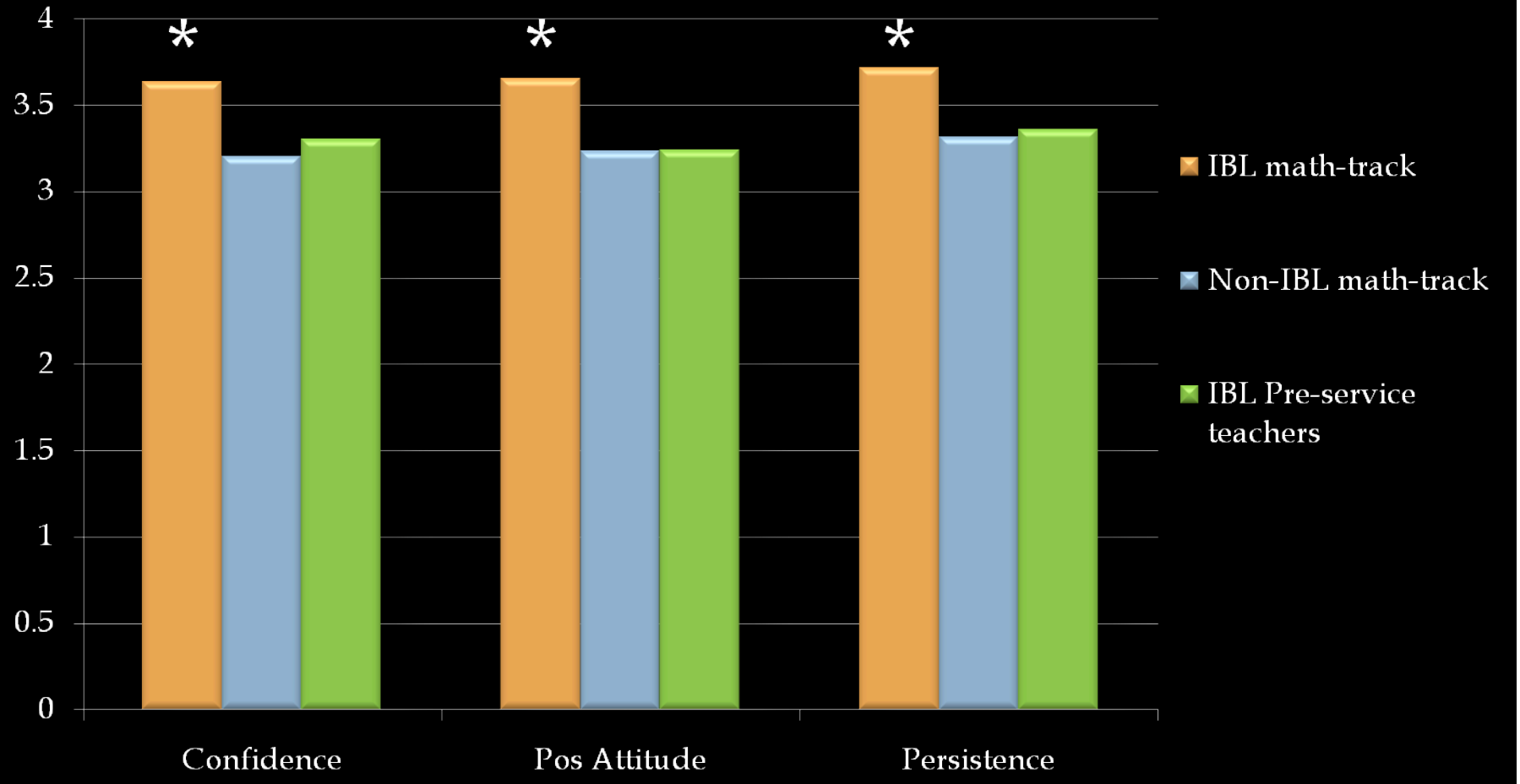
Cognitive gains from survey

IBL: N= 503-530; Non-IBL: N= 294-328; IBL pre-service teachers: 166-168.
Scale from 1 = no gain to 5 = great gain



Affective gains from survey

IBL: N=520-529; Non-IBL: N=320-325; IBL pre-service teachers: N=166.
Scale from 1 = no gain to 5 = great gain



Summary of findings, IBL vs. non-IBL

Self-reported learning gains - cognitive, affective, social -
are highest overall for IBL math-track students
are highest for IBL pre-service teachers in application, teaching

Interviews corroborate these gains & their nature

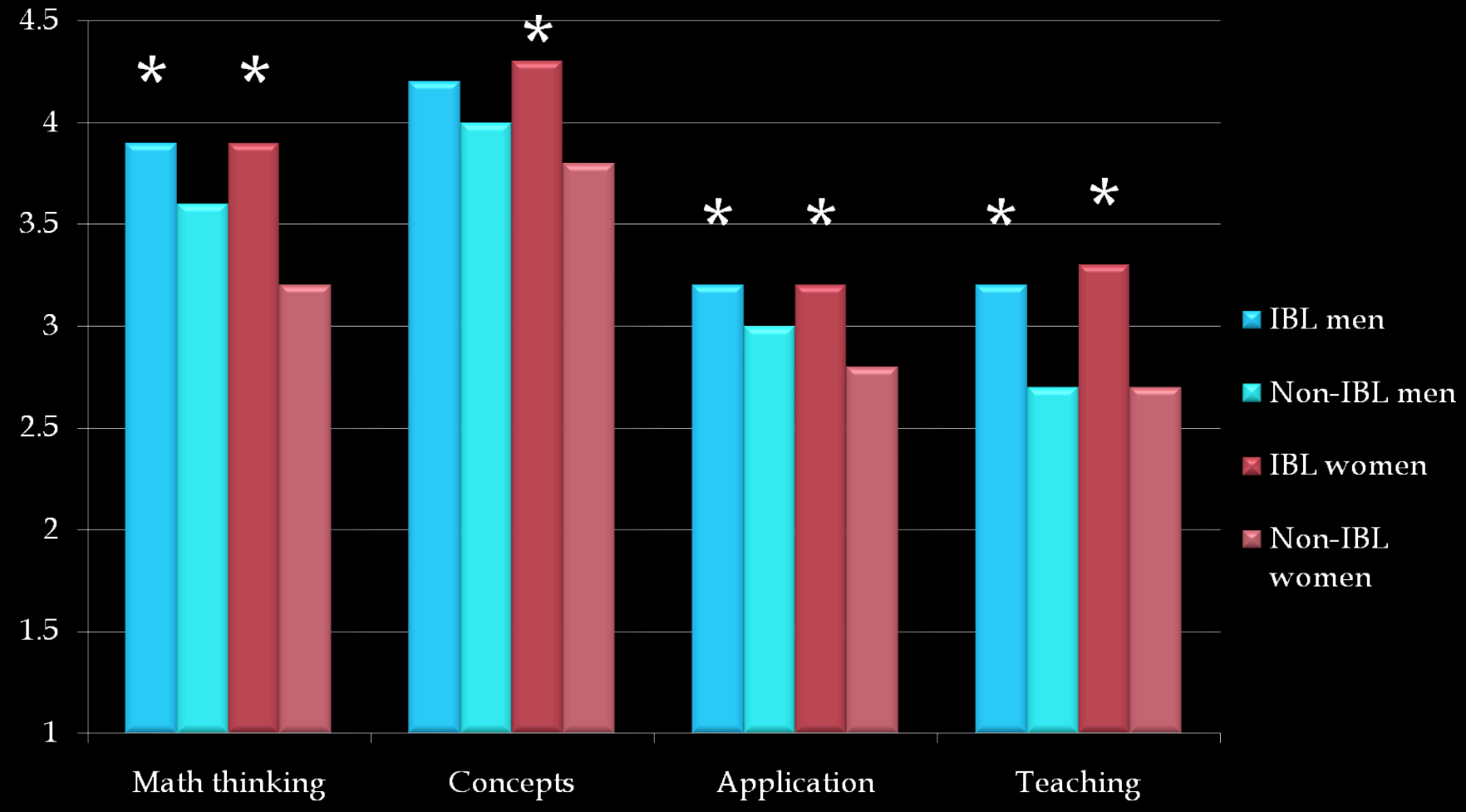
Attitudes (pre vs. post-course)
Interest in mathematics as a major; as a personal interest
increases modestly for IBL students
declines slightly for non-IBL students

Tests show that IBL students apply slightly more sophisticated criteria when evaluating mathematical arguments

Later courses
IBL students earn grades as good or better than peers
IBL students take as many or more courses

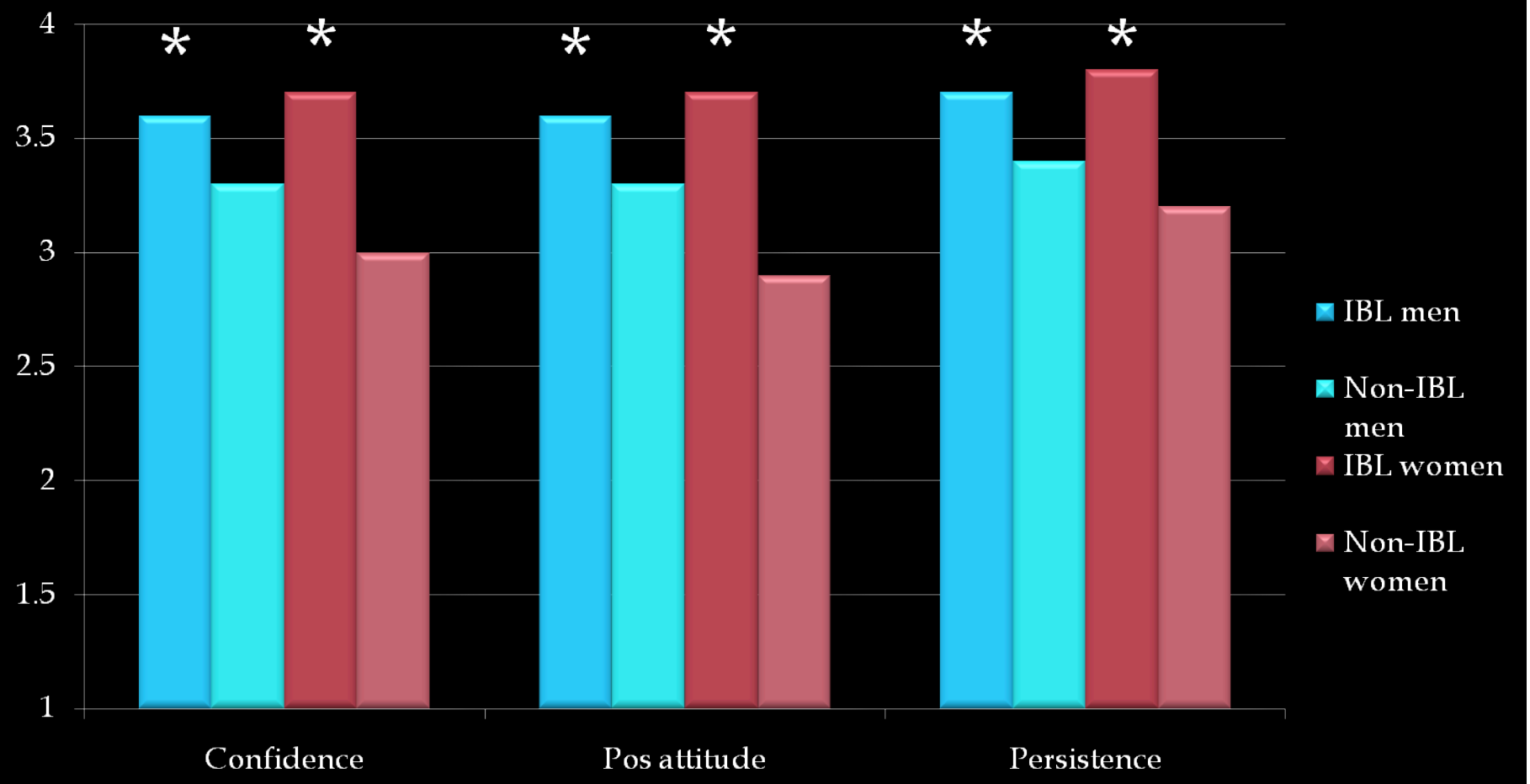
Cognitive gains from survey, by gender

IBL men: N=347-353; Non-IBL men: N=230-231. IBL women: N=181-182; Non-IBL women: N=90-91. *Scale from 1 = no gain to 5 = great gain.*



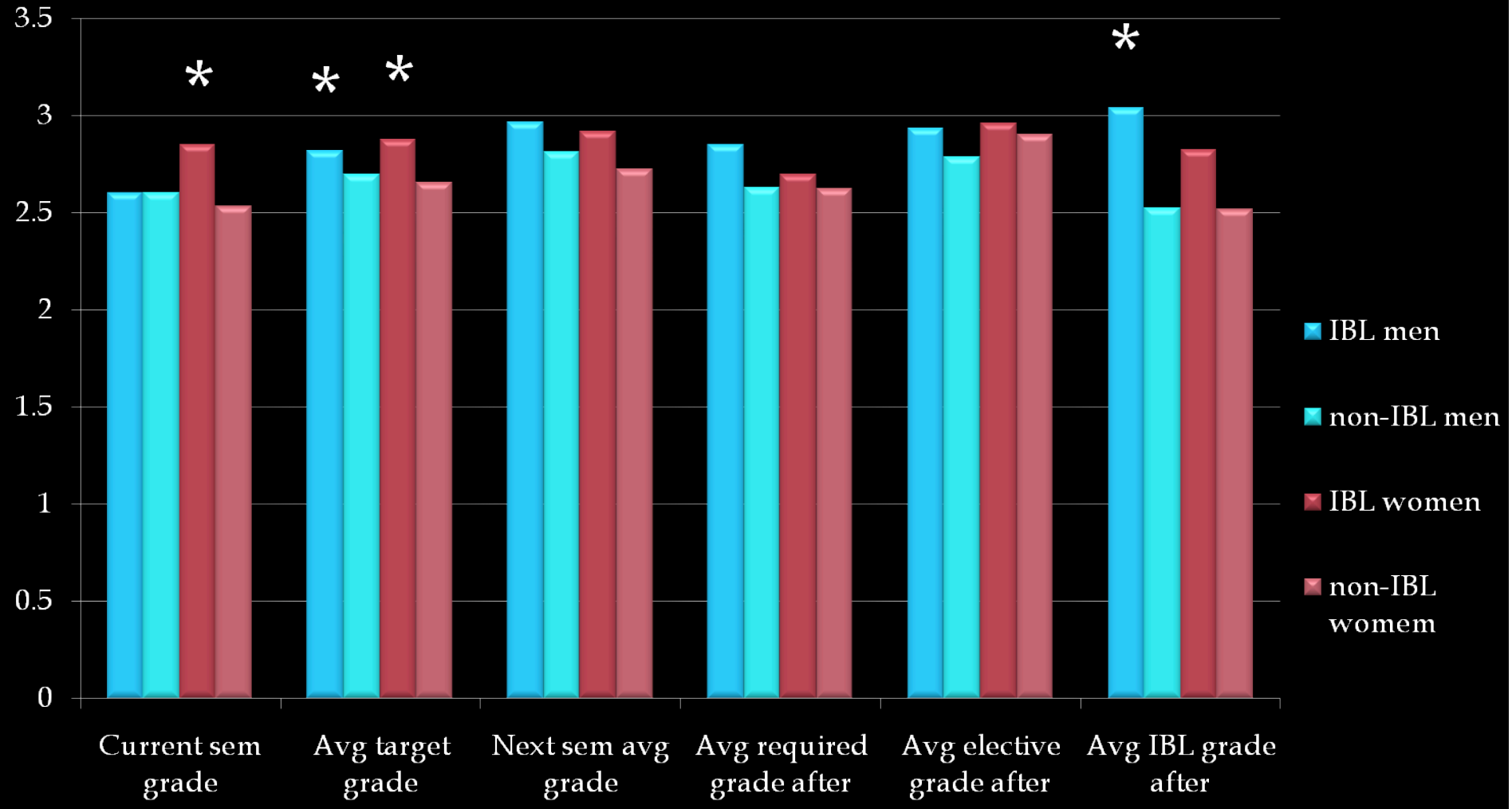
Affective gains from survey, by gender

IBL men: N=351-355; Non-IBL men: N=227-229. IBL women: N=181-184;
Non-IBL women: N=88-90 *Scale from 1 = no gain to 5 = great gain.*



IBL's benefits for women are somewhat sustained: Grades after target course, by gender

IBL men: N=22-147; Non-IBL men: N=51-755. IBL women: N=8-57; Non-IBL women: N=29-322. *Scale from 0.00 = F to 4.00 = A.*



Summary of findings on IBL and gender

Self-reported learning gains - cognitive, affective, social -
are lowest for non-IBL math-track women
are equal overall for IBL math-track men & women
(IBL women write in more gains too)
∴ IBL levels the playing field for women in this class

Attitudes (pre vs. post-course)
Confidence & motivation increase slightly for IBL women
Confidence, collaboration, use of effective learning strategies decline more noticeably for non-IBL women

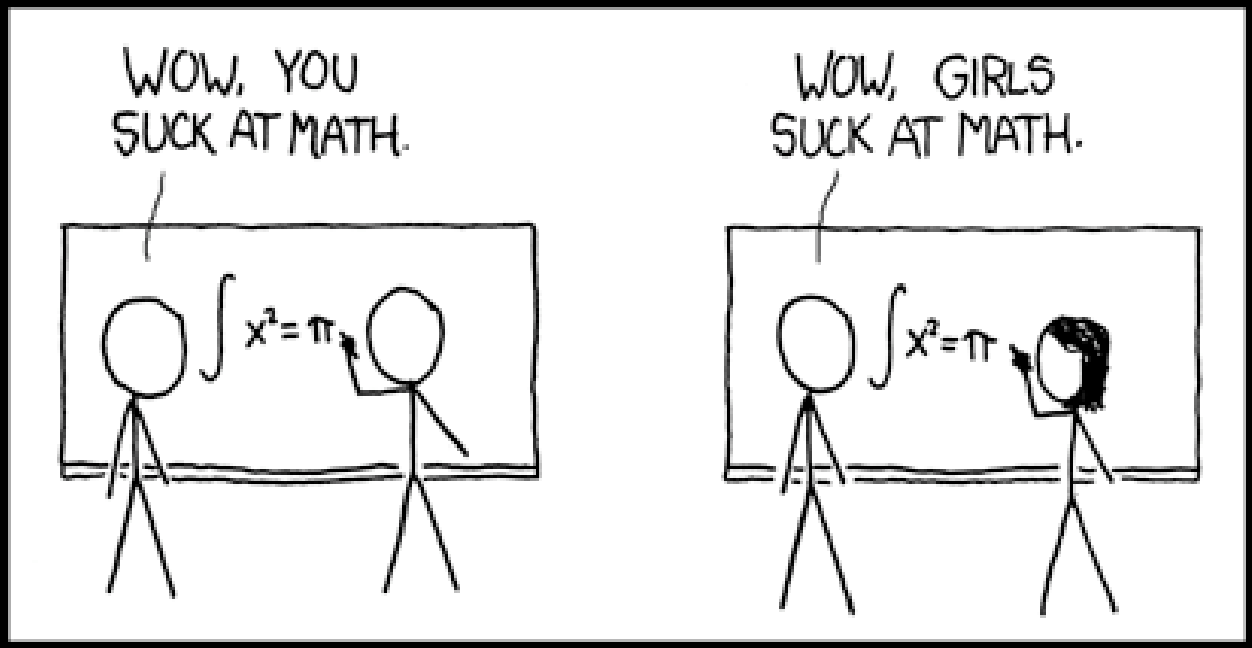
Later courses
IBL women's gains are partially sustained
(∴ the playing field does not remain level)

Why?

Interview data: few gender differences at all. Others' real performance becomes visible??

Older research: chilly classroom climate, dearth of women peers & role models

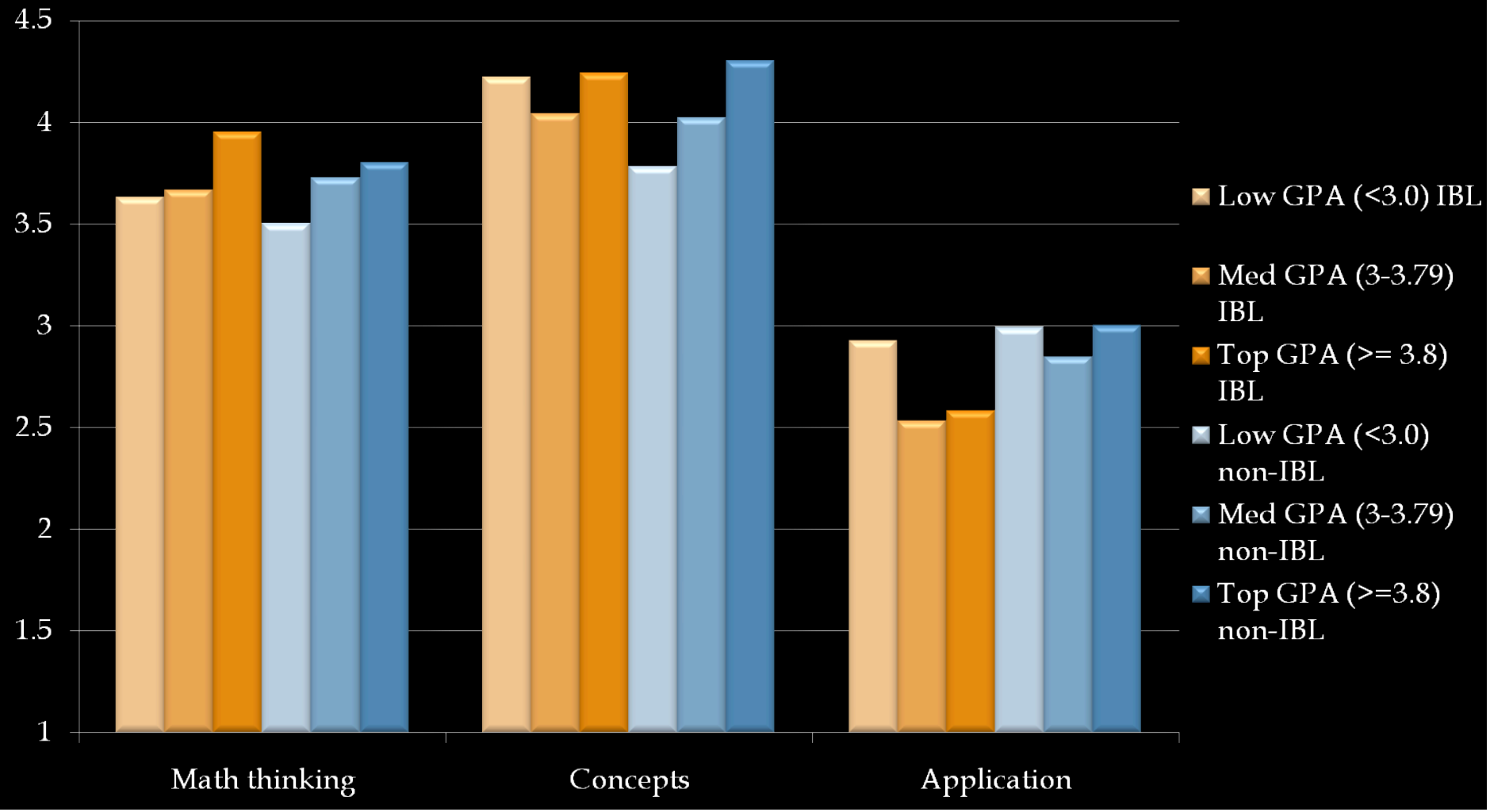
Recent research: stereotype threat is especially powerful for women and math



xkcd.com/385

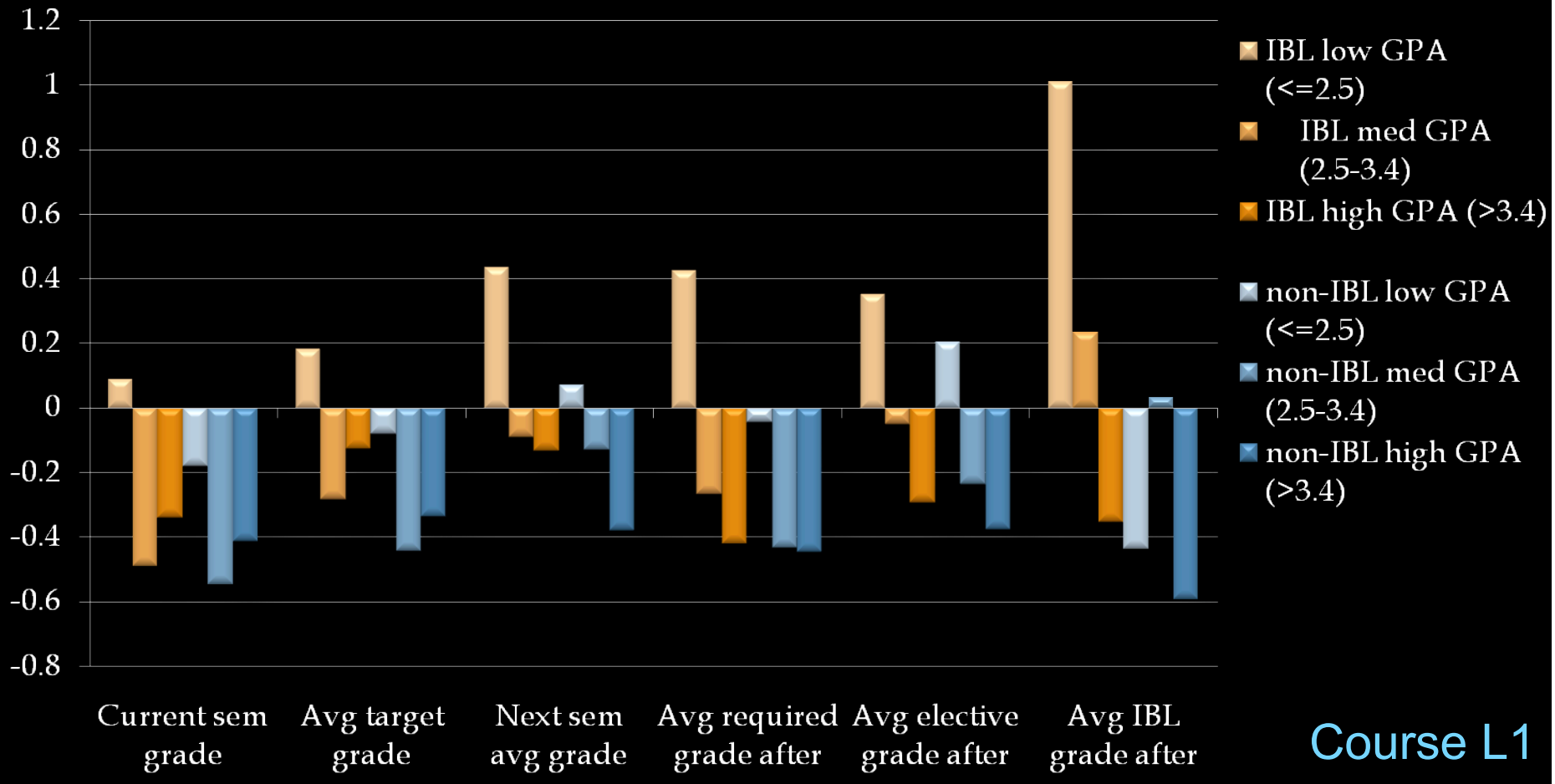
Cognitive gains from survey, by achievement group

Non-IBL - Low: N= 16-18; Medium: N= 52-54; Top: 19-20.
IBL - Low: N= 44-45; Medium: N= 161-162 Top: 81-82. *Scale from 1 =no to 5 = great gain*



Grade improvement (before/after course), by student prior GPA

Non-IBL - Low: N= 37-360; Medium: N= 21-353; Top: N= 22-364.
IBL - Low: N= 7-49; Medium: N= 8-76; Top: N= 15-79. *Scale from 0.00 = F to 4.00 = A*



Course L1

Summary of findings on IBL and achievement

Self-reported learning gains - cognitive, affective, social -
are highest for IBL low-achievers,
especially for pre-service teachers
Also higher than non-IBL peers
No differences for higher-achieving students

LMT pre/post-test for pre-service teachers
Low achievers make the greatest score increases

Later courses
IBL low achievers' grades improve
while later grades decline for all others, IBL or non-IBL
(Low achievers do not take more courses)
No harm to high achievers (& they may take more courses)

Three claims about student outcomes

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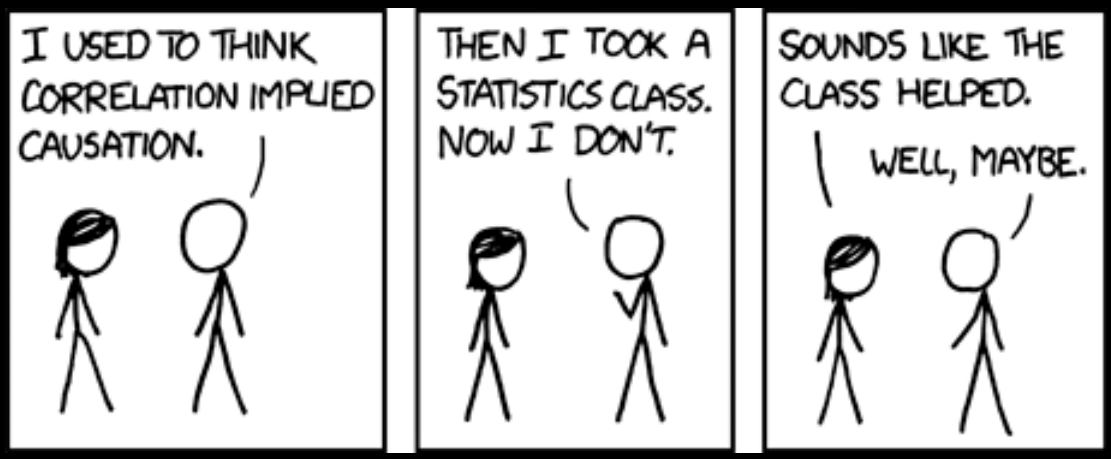
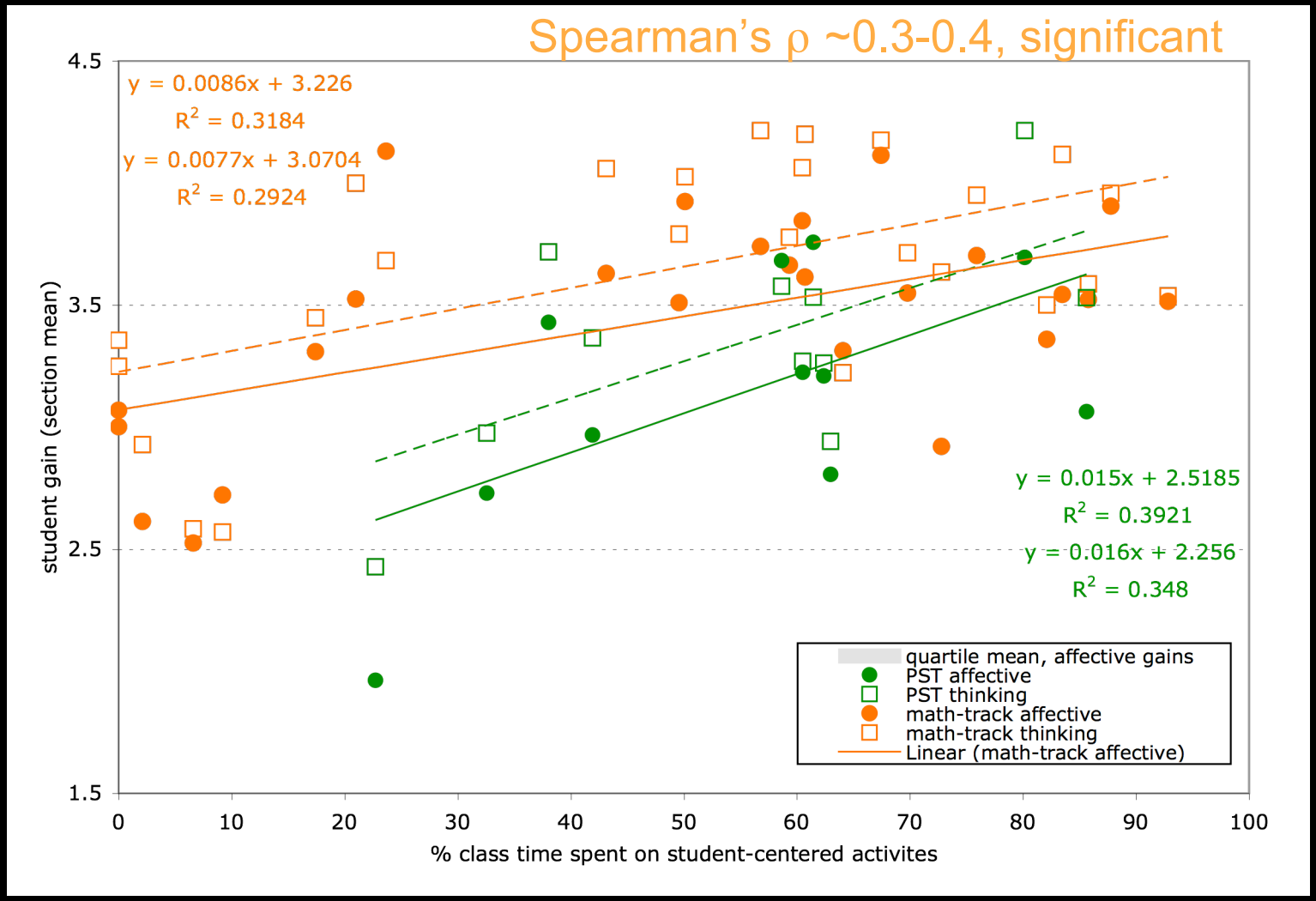


Why do we think this is related to use of IBL methods?

Correlation of student learning gains with instruction



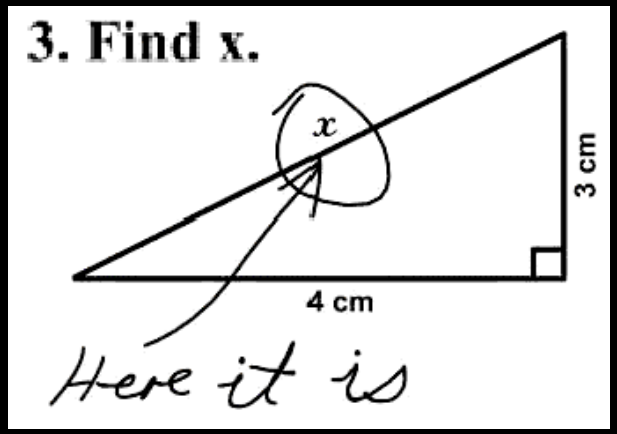
Student gains also correlate with observer ratings of interactions, atmosphere

Take-home message

Changing *instructional activities* - how students meet the mathematics - toward more student-active approaches enhances student learning

Refining *practice of IBL methods* - everyday choices and acts of teaching - shapes & strengthens the key learning processes of engagement & collaboration

Conclusions



Patterns across multiple outcome measures are robust despite sizable & realistic variation:

IBL benefits students

IBL benefits women & boosts low-achieving students, with no harm to men or high achievers

Student outcomes are clearly linked to classroom use of active-learning approaches

Collaboration & deep engagement with mathematics are critical learning processes

Choose your practices to optimize & reinforce these!

www.colorado.edu/eer/research/steminquiry.html