Analyzing the Effectiveness of a Developmental Courses, an Artificially Intelligent Tutor and Supplemental Instruction for a Gateway Chemistry Course

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Abstract

This study compared two of the four most common responses to help underprepared students succeed in challenging "gateway" courses, such as C117, *Principles of Chemistry and Biochemistry* at IU. This study compared the eventual success in C117 of groups of students who did not meet criterion on the IU C117 entrance exam. One group chose to complete a $70 artificially intelligent tutor known as *ALEKS.* The second group chose to complete C103, a five-credit developmental chemistry course, and were substantially less well-prepared than the first group. Propensity-score matching techniques were used to equate the two very different groups of students. Both groups of students earned lower grades in CHEM117 than students who passed CHEM117 placement exam. But the grades of students completing the ALEKS program (reportedly averaging ~ 30 hours) grades were not statistically different from the grades of the students who completed C103 (ostensibly 225 hours). AI tutors are an effective alternative to development courses; course improvements led to significantly improved grades of both groups of under-prepared students.

ACKNOWLEDGEMENT

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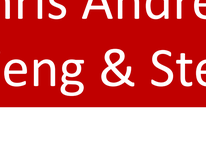
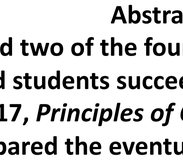
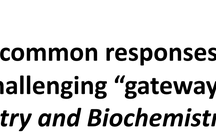
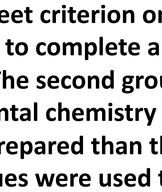
BIG PROBLEM: Remedial Developmental Education (DE) course are typically ineffective

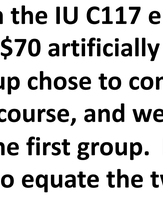
- Overwhelming evidence that few DE students go on to pass targeted course
  - stigmatize students
  - exhaust financial aid
- But DE persists
  - Courses generate tuition
  - Fits in structure
  - Can use adjuncts
- IU is prohibited from non-credit courses
  - Offer lots of DE courses whose credits are not accepted
- Seven major Higher Ed groups say "scrap existing DE"
  - Contextualize any DE
  - Provide supplemental instruction











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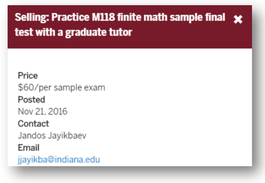
ALTERNATIVE #1: One-on-one private tutors are very effective as SI (but too expensive)

- Average effect size of human tutors is .70 (Van Lehn, 2011)
  - Bloom's famous (1984) 2.0 ES was inflated
  - Too expensive for schools to offer
  - Too expensive for many students to buy
  - Evidence that tutors cheat, leading to passing grade but subsequent failure.
  - Cost declining with online overseas tutors



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ALTERNATIVE #2: Reduce admission criteria and provide peer-based SI (promising)

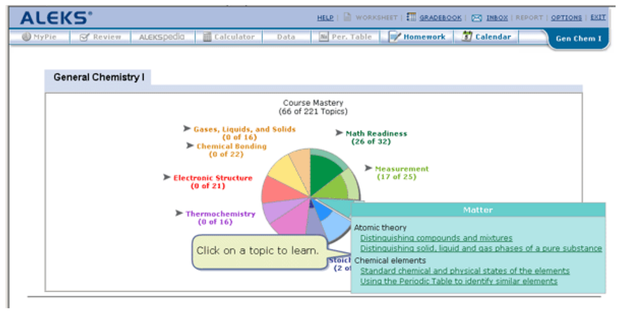
- Peer-Assisted Study Sessions (PASS) is the most popular model
  - Promising evidence and growing use
- But SI does not generate tuition
  - No evidence of *relative* return on investment
  - Requires additional non-course infrastructure
  - Some evidence SI narrows learning

Supplemental Instruction

PASS PEER ASSISTED STUDY SESSIONS

ALTERNATIVE #3: Replace DE with Artificially-Intelligent (AI) tutors, offer SI (more promising)

- McGraw Hills Adaptive Learning in Knowledge Spaces (ALEKS)
  - Adaptive questioning identifies weaknesses
  - Gives students content that they are ready to learn
  - Chemistry Review costs $70



SPECIFIC PROBLEM: It is difficult to compare effectiveness or return on investment (ROI) across alternatives to justify costs

- Hundreds of studies of PASS but very few feature random assignment
  - Very difficult to randomly assign students in real context
- Self-selection is a massive problem because it confounds comparison
- Almost no studies of return on investment on *any* of these alternatives
- Big source of tension between faculty, departments, and colleges

RESEARCH CONTEXT: Jill Robinson's CHEM117 *Principles of Chemistry and Biochemistry*

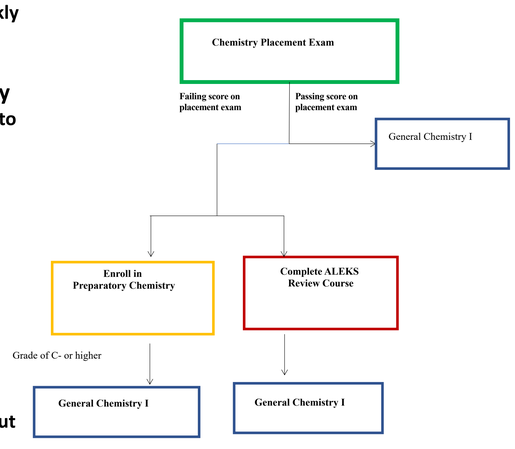
- Jill is an award-winning Senior Lecture
  - Leading CHEM117 since 2002
  - President's awardee for Distinguished Teaching
  - Lead author of a popular textbook used in the course
  - Works closely with Cate Reck on CHEM117
- Jill has extensively refined CHEM117
  - Began requiring digital homework from textbook starting in 2014
  - Made extensive changes starting in 2015, including TA ratio, TA training on active learning, active learning classrooms, introduced new assignments and weekly quizzes.
- Jill created the CHEM117 entrance exam and tracks performance closely
  - Need a score of 15 (out of 30) to get into CHEM117
  - Also admitted with SAT Math > 580 or ACT Math > 25
- Jill supervises CHEM103 *Intro to Chemical Principles*
  - Five-credit DE course on high school chemistry.
  - Likely a better course than typical DE courses
  - Ostensibly requires 225 hours and requires paying for five credits.
  - Credits count towards some degrees but not others (GenEd N&M credit)
  - Must earn a C- or better to get into C117
- ALEKS was introduced as an alternative to C103 in 2013
  - Costs $70, must get 90% mastery

C103 - Introduction to Chemical Principles (5 cr.)

Content includes applications of measurement and chemical formula/equation conversions; modern view of the atom; and solution processes that relate to chemical reactions. Lectures, labs and discussion sections will be problem-solving strategies. Credit given for only one of C101-C121, or C103.

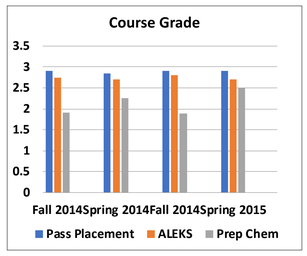
C117 - Principles of Chemistry and Biochemistry I (3 cr.)

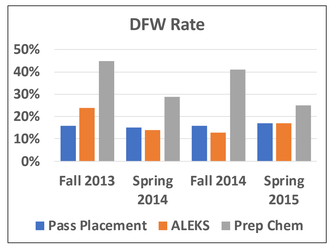
Lecture course covering basic principles of chemistry and biochemistry, basic mathematical and conceptual principles in atomic structure and periodic properties, molecular structure, chemical bonding, energy (thermochemistry), kinetics, equilibrium and thermodynamics. Credit given for only one of the following: C105-C125, C117-C127, or S117.

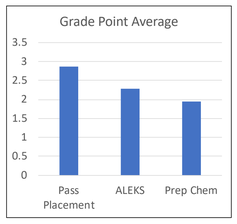


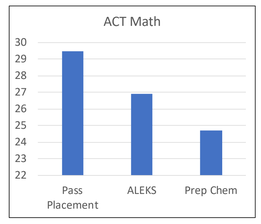
DATA AND PARTICIPANTS: Final grades of 727 CHEM117 student who did not pass entrance exam

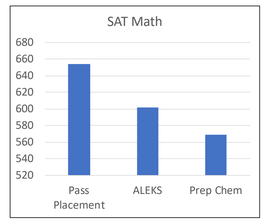
- 542 chose to complete ALEKS
  - Reported spending an average of 30 hours
  - Test scores and GPA were indeed lower than the students who passed the entrance exam
  - Test scores and GPA were relatively higher than student who elected to take CHEM103
  - Average C117 grade of 2.61, slightly lower than average grade of students who passed entrance exam
- 185 chose to complete C107
  - Test scores and GPA were substantially lower than students who complete ALEKS
  - Average C117 grade of 1.71 over the years was substantially lower than students who complete ALEKS
  - Showed a dramatic improvement in CHEM 117 grades with course improvements in 2015
- Compared both with other students who tested directly into course











LEARNING ANALYTICS CHALLENGE: Is ALEKS *really* more effective than C103

- Impossible to directly compare the two groups because they are so different
- It is possible the C103 is *more* effective given the lower test score and GPA of those students
- This is what propensity score matching (PSM) is for.
  - Many different models
  - All use other data to take into account the propensity for ending up in one group versus another
  - Nearest neighbor method drops subjects until the groups are equivalent
- Combined data from Chemistry Department with demographic data from BAR
  - Used gender, ethnicity, SAT math, high school GPA
  - Likely a better course than typical DE courses
- Nearest neighbor matching selected 122 (of 542) who completed ALEKS and 142 (of 185) students who took CHEM103

RESULTS: No difference in final grades for ALEKS vs. CHEM103 students ($T = 0.99$)

CONCLUSION #1: ALEKS AI Tutor (about 30 hours & $70) is as effective as C103 (5 credits tuition & ~ 225 hours) in terms of final grade

CONCLUSION #2: Course improvements and Supplemental Instruction in 2015 were particularly helpful for the CHEM103 who were particularly at risk of failing C117.

HOPEFUL NEXT STEPS: Analyze more recent data with improved SI, get $ data and study ROI, help other departments implement this model,