Engaging 1st and 2nd Year Science Students in a Course-Embedded Authentic Research Project

Center for Authentic Science Practice in Education

CASPiE

CASPiE

Authentic Practice

- The CASPiE model defines “authentic science practice” as laboratory experiences involving students in the generation of *new* scientific knowledge through experimentation.
- This differs from inquiry-based teaching

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Type of Laboratory Continuum

Less student responsibility

More student responsibility

Verification/ **Traditional** labs in class	Guided Inquiry labs in class	Open Inquiry labs in class	Research-based labs in class **(CASPiE)**	Research apprentice-ship in a lab

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Goal

Introduce an authentic research experience into freshman and sophomore course laboratories in order to increase student retention in the sciences.

Strategy

- Laboratory experiments based on authentic research ***modules***
- Access to research-level instrumentation ***instrument network***
- Create a research group / scientific community environment ***PLTL***

Research Modules

- Critical component #1:
  - Data collected by students contributes to author's research
- Critical component #2:
  - To be accomplished by 1st or 2nd year students in their normal laboratory courses (6-8 weeks, one 3 hr block per week)
    - Research module author does not need to be involved in teaching the course or be present in the lab

Module Structure

- Intro
  - Big picture
  - Chemistry connections
  - The students' role
  - Module calendar
- Skill Building sessions (2-3 weeks)
  - Intro to technique
  - Materials and equipment
  - Procedures
  - Pre and post lab
- Research sessions (3-4 weeks)
  - Intro and readings from the literature
  - What is known and what is not known
  - Suggestions for research directions
  - Product/output for the scientist/author

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Original Set of Research Modules

- Ion sensors using surface protection/deprotection
- Antioxidants in foods
- Solid-phase organic synthesis
- Band-gap tuning of ZnO_x films for solar cells
- The enzyme system in dairy products
- Lipids and fatty acids
- Biodiesel from waste fats
- Small molecule antiviral drug discovery

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Peer-Led Team Learning in CASPiE

- Students work in teams of three in lab
- Each peer leader facilitates teams of three in "workshops"
- PLTL groups work as a team on problems related to the research
- Peer leaders NOT involved in curriculum development or assigning marks

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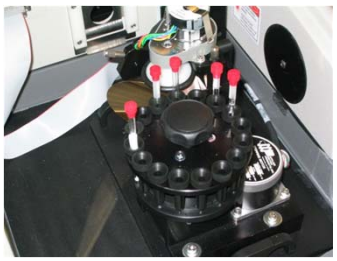
The CASPiE Model for Instrumentation

- Research-quality data requires research-quality instrumentation
- High cost → purchase only one of each
  - Equip with autosamplers
  - Enable remote access
  - All institutions can use



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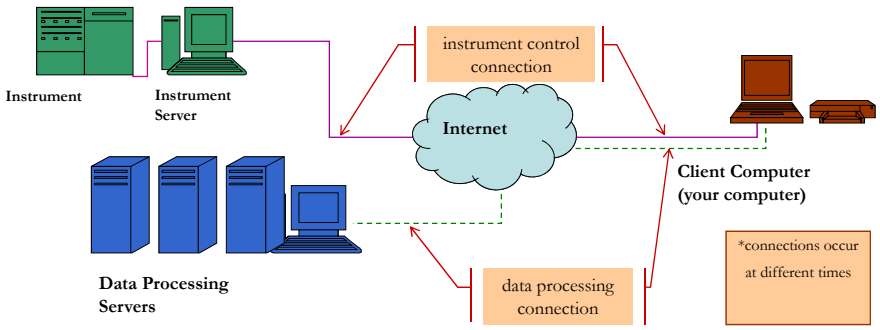
Instrument Network Diagram



- Connection requires only an Internet browser and free plug-in

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Current Instrumentation

- FT Raman Spectrometer
- HPLC with Diode Array
- Gas Chromatograph/FID
- Gas Chromatograph/Mass Spectrometer

Note: over 1,300 HPLC samples were run in a four week period during March 2007.

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Various Operation Modes

- "Batch" Mode:
  - Beginning students submit samples to be run for them.
  - Students access their data and processing software only.
- "Individual" Mode:
  - Advanced students access the instrument to run their samples
  - They subsequently access and process their data.
- Demonstration mode for teaching (advanced user, such as instructor, runs system while others observe.)
- Video cameras allow for observation of lab and instrument activities.

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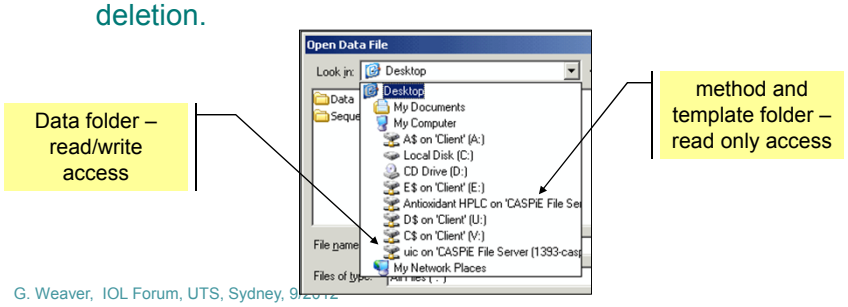
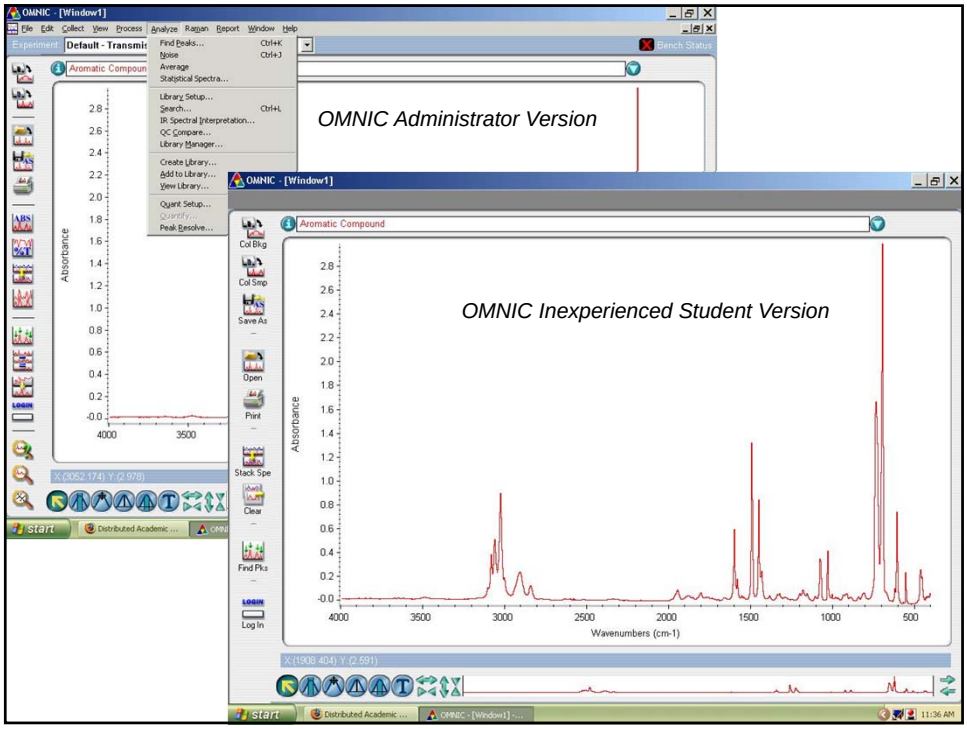
Protecting the Data

- *Restrict Data File Access* – Students should only be able to open and manipulate their own data.
  - Map drive to specific file server share folder at login.
  - Set share permissions to allow data modification but not deletion.



G. Weaver, IOL Forum, UTS, Sydney, 9/25/12



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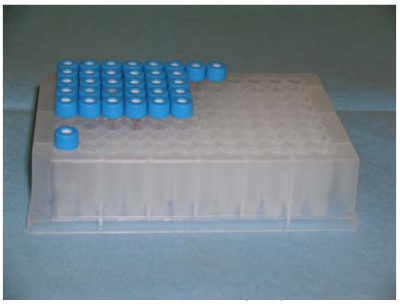
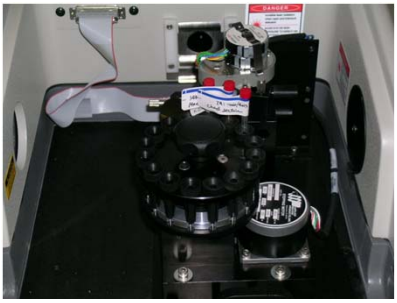
High Throughput via Autosamplers

- *Minimize Sample Load Time* – When possible, samples are shipped in autosampler trays.





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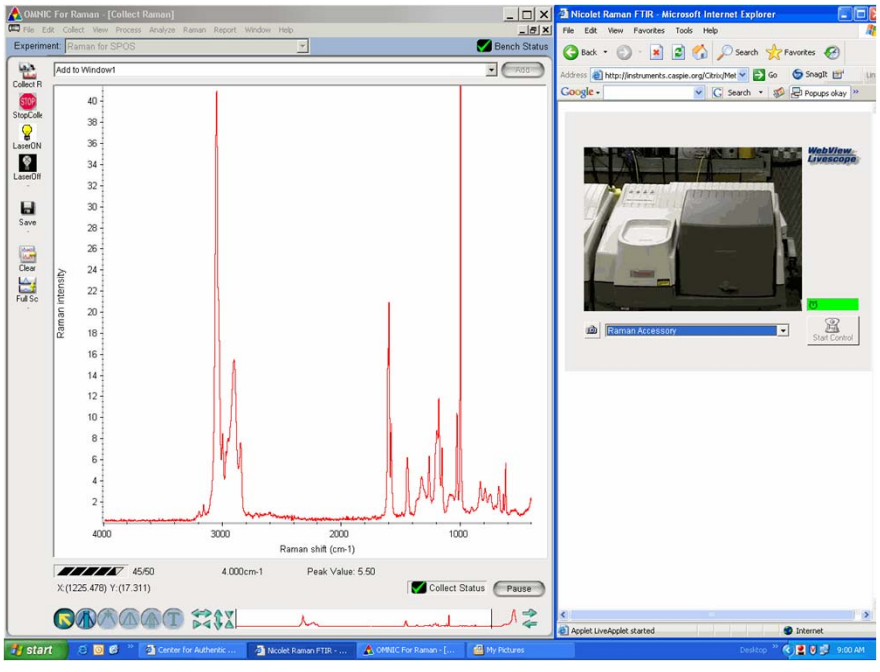
WebView
Livescope
Raman Full View
Start Control


OMNIC For Raman - [Collect Raman]
Experiment:
Raman for SPOS
Bench Status
Add to Window1
Raman intensity
Raman shift (cm-1)
4000
3000
2000
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X:(1225.478) Y:(17.311)
Collect Status
Pause
Nicolet Raman FTIR - Microsoft Internet Explorer
WebView
Livescope
Raman Accessory
Start Control
start

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Scope of CASPiE Usage

- Original Chemistry CASPiE
  - 2005-2011
    - ~6000 students
    - ~17 institutions (including 1 in Australia: UQ)
    - ~30 workshop participants (3 workshops)
- Branching Out
  - 2008: CASPiE grant (NSF) in Atm. Sci.
  - 2009: CASPiE grant (NSF, HHMI) in Biology
    - Winner of 2012 *Science* prize for inquiry teaching
- Secondary schools

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Extensive Research and Evaluation

- Student end-of-semester surveys
  - Single institution, 1-yr item-level analysis
  - Across institutions, multiple yrs, factor analysis
- Interviews comparing Trad, CASPiE, inquiry
- Longitudinal Study
  - 2 institutions (PhD granting)
  - Academic records analysis
  - Surveys/interviews – retrospective
- Group dynamics – tertiary and secondary

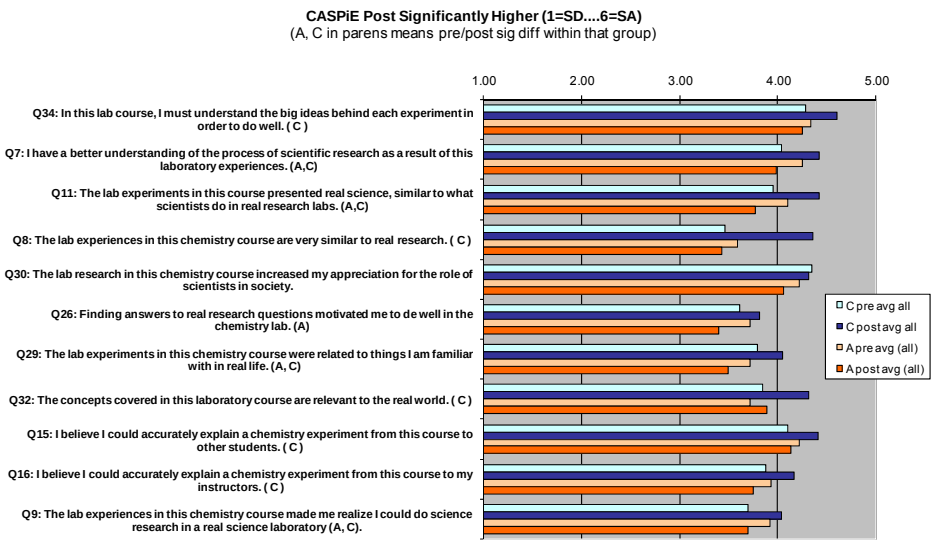
Snapshot Survey Analysis

- Jan-May 2007, 1 institution
- Randomly assigned CASPiE/Traditional

N	CASPiE	Traditional
Total	299	253
Male	185	145
Female	114	108

Item-level Analysis

- I have a better understanding of the process of scientific research as a result of the laboratory experiences in this chemistry course.
- The lab experiences in this chemistry course made me realize I could do science research in a real science laboratory (for instance at a college, or with a pharmaceutical company).
- I believe I could accurately explain a chemistry experiment from this course (including the significance of the results) to other students // my instructors.
- The lab experience in this chemistry course has made me more interested in science ***//*** a science career ***//*** earning a Masters degree in a science field.
- Finding answers to real research questions motivated me to do well in the chemistry lab.



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Comparison of Exam Scores

Purdue Sections – Spring 2007

A-section values	Total	Exam 1	Exam 2	Exam 3	Exam 4
avg	879.39	121.21	103.79	98.16	190.00
std dev	178.37	22.80	28.36	27.61	51.84
C-section values					
avg	860.65	118.32	99.54	94.96	182.54
sdev	201.04	27.08	29.57	27.12	54.86

No statistically significant differences

- CASPiE labs began 1 week before Exam 3

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Factor Analysis

- 34 items, 6-position Likert scale.
- Factor Analysis uses 30 items

Factor	Cronbach α
1. Interest in Chemistry/Science	0.924
2. Perceived connection between real life and science	0.899
3. Lab perceived as similar to real scientific lab practices	0.804
4. Perceived learning of chemistry content through laboratory (self-assessment)	0.808
5. Belief that they can understand and do scientific research (self-efficacy)	0.800
6. Perceived value of collaborative work in lab	0.504

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Statistical Data for AY's 07/08, 08/09, 09/10

- Respondents:
  - N = 930 CASPiE participants (60% female)
  - N = 1006 non-participants (53% female)
- 9 institutions
  - 4 are 2-year colleges
- 5 different modules
  - 1st (General) and 2nd (Organic) year

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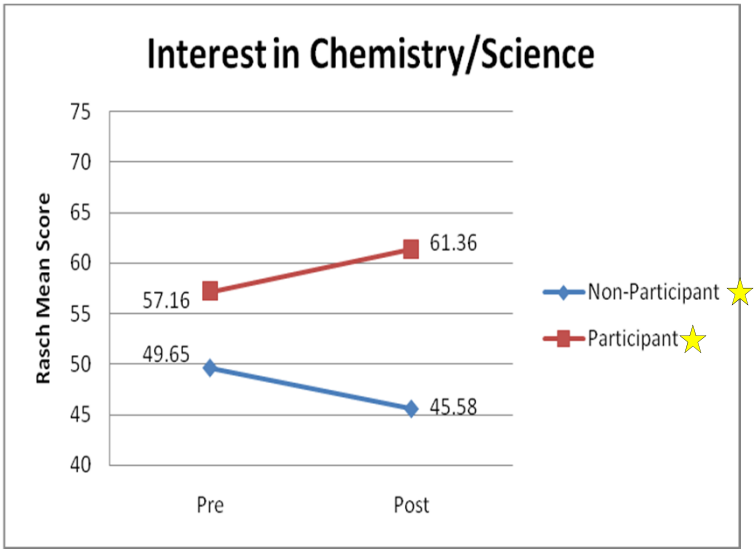

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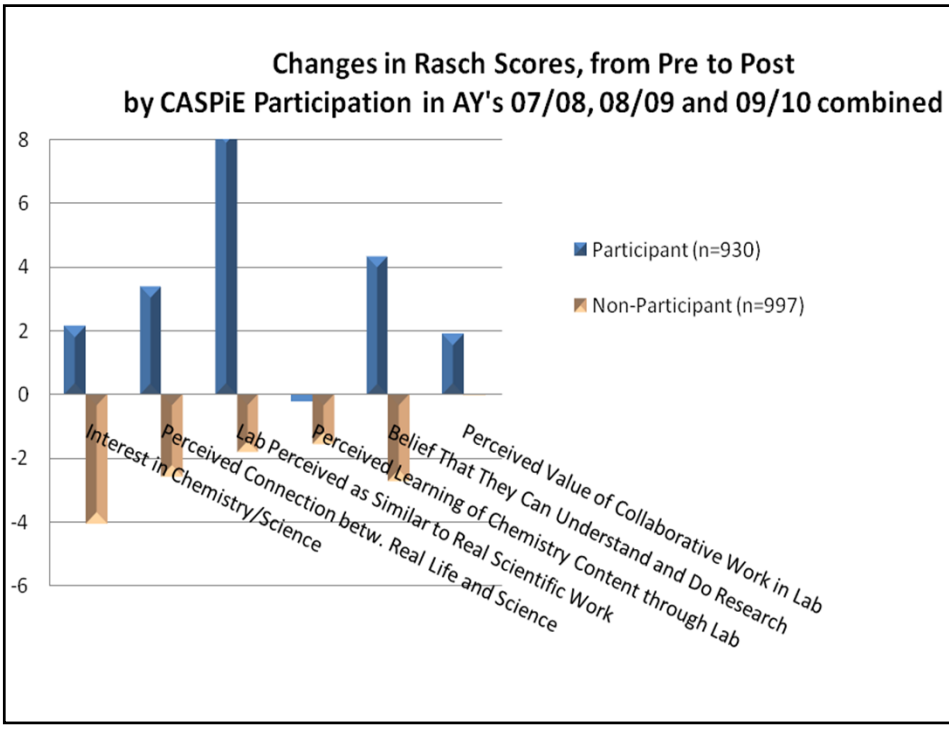

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Interview Methodology

- 1 Masters' and 3 PhD institutions
- Two 15-60 minute semi-structured individual interviews
  - N = 55
- Entrance during the first five weeks of classes; exit during last two weeks
  - 2nd semester General Chemistry
- $25 compensation upon completion of both interviews

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Comparing Inquiry/Traditional/CASPiE

Changes in ability to describe the main idea of the experiment.

	No change		Negative change	Positive change
	Consistently unclear	Consistently clear	Clear to unclear	Unclear to clear
Traditional	**50%**	**30%**	**10%**	**10%**

CASPiE

Comparing Inquiry/Traditional/CASPiE

Changes in ability to explain the results of the experiment.

	No change		Negative change	Positive change
	Consistently unclear	Consistently clear	Clear to unclear	Unclear to clear
Traditional	**54%**	**36%**	**10%**	**0%**

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Comparing Inquiry/Traditional/CASPiE

Summary of students' descriptions of experimental next steps.

	Entrance			**Exit**		
	Don't know / Would not do one	Repeat experiment	Extension of experiment / Complex response	Don't know / Would not do one	Repeat experiment	Extension of experiment / Complex response

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Longitudinal Assessment

- Effects on CASPiE participants with respect to:
  - Grades in subsequent chemistry courses
  - Time to graduation
  - Retention in STEM
  - Retrospective views on the experience
- Comparison to students in traditional lab courses as control groups

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Academic Records Sample Set

Spring-Year	CASPiE (N)	Traditional (N)	Waitlist (N)	Opt-in
2006	22	119*	12	√
2007	332	317	N/A	
2008	70	118*	N/A	√
2009	191	203*	N/A	√

- Data collected from all CASPiE and waitlist students
- Data collected from traditional students includes:
  - All from one section of 2007
  - *Other years by systematic sampling

Opt-in Cohorts: Comparison of Grades

	CASPiE (N = 244)		Traditional (N = 357)		Waitlist (N = 10)	
Course	Avg. Grade	St. Dev	Avg. Grade	St. Dev	Avg. Grade	St. Dev
CHEM1a	3.19*	0.84	2.88	0.80	3.10	0.74
CHEM1b+	3.23*	0.91	2.85	0.94	3.00	0.82

*p<0.05
+Semester of CASPiE implementation
CHEM1a= First semester general chemistry
CHEM1b= Second semester of general chemistry

Opt-in Cohorts: Comparison of Grades

	CASPiE (N = 45)		Traditional (N = 41)	
Course	Avg. Grade	St. Dev	Avg. Grade	St. Dev
CHEM1a	3.41*	0.77	3.04	0.78
CHEM1b+	3.38*	0.75	2.88	0.81
CHEM2XX	3.42*	0.59	2.99	0.57
CHEM3XX	3.20	0.94	2.93	0.82

*p<0.05
+Semester of CASPiE implementation
CHEM1a= First semester general chemistry
CHEM1b= Second semester of general chemistry
CHEM2XX= Average 200 level chem courses
CHEM3XX= Average 300 level chem courses

Random Cohort: Comparison of Grades

	CASPiE (N = 240)		Traditional (N = 227)	
Course	Avg. Grade	St. Dev	Avg. Grade	St. Dev
CHEM1a	3.01	0.81	3.13	0.71
CHEM1b+	2.62	1.05	2.79	0.94

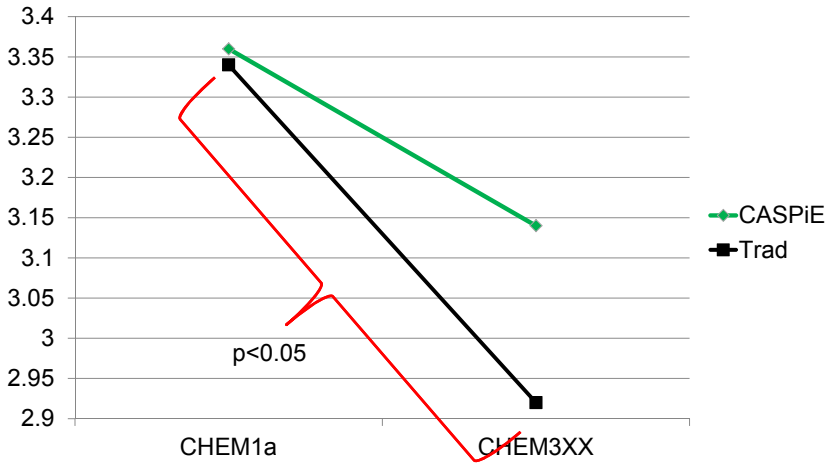
+Semester of CASPiE implementation
CHEM1a= First semester general chemistry
CHEM1b= Second semester of general chemistry

Random Cohort: Comparison of Grades

	CASPiE (N = 28)		Traditional (N = 32)	
Course	Avg. Grade	St. Dev	Avg. Grade	St. Dev
CHEM1a	3.36	0.49	3.34	0.60
CHEM1b+	3.14	0.76	2.97	0.82
CHEM2XX	3.17	0.66	2.91	0.74
CHEM3XX	3.14	0.88	2.92†	0.86

† $p<0.05$ within group

Random Cohort: Comparison of Grades



Graduation Rate

Institution 1

		CASPiE	Traditional	Waitlist
Average time to graduate	R	4.49	4.53	
	O	4.08*	4.25	4.27

R: Random, O: Opt-in

Institution 2 (all R)

		CASPiE	Traditional
Average time to graduate	(All)	4.11*	4.23
	F07		4.45
	S08	4.14*	

*p<0.05

Summary of Longitudinal

- Opt-in students higher performing initially, and maintain that lead
- Randomly assigned students may get a "protective" effect from CASPiE on later performance
- CASPiE may help reduce time to graduation
- No differences seen in STEM major retention/migration or research activity

Long-term Benefits

- CASPiE students were more likely to report that they had learned how to conduct research and that their lab work was a rewarding experience

	CASPiE	Traditional
Learned how to do research	25%	0%
Liked course	55%	19%
Did not like course	19%	11%

Self-efficacy and Sense of Accomplishment

- CASPiE students more likely to report feeling confident to do research and getting a sense of accomplishment from doing their laboratory work

	CASPiE	Traditional
Yes self-efficacy/sense of accomplishment	52%	15%
No self-efficacy/sense of accomplishment	10%	41%

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Long-term benefits

- CASPiE students referred to their group work as positive because they felt a sense of scientific community
- CASPiE students thought their experience helped them narrow down and focus on a career path, whereas traditional students thought their experience helped with future courses

	CASPiE	Traditional
Sense of community	25%	7%
Career focus	42%	22%
Help with future courses	50%	64%

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Student Quotes

- "It's kind of exciting…You don't get it [the results] and you get a little bit disappointed, but you try to improvise and next time you end up getting a good result and you get excited. So you kind of want to do it more…It's exciting."
- "It made it feel more official. It wasn't so much the cookbook labs where someone already knows the answer…But it felt more official. Having kind of a real lab setting, we were actually doing research."
- "I really liked that we got to learn something about real research…And the fact that each lab actually built on the one before instead of every single lab being different and not related."
- "It was just very motivating to think that maybe we can find something that might be used somewhere. That idea itself was enough to really feel fulfilled from these kinds of experiments and work."
- "You get a sense that you're doing something that has an impact on the world as opposed to experiments that are just to teach you something."

CASPiE

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