Undergraduate Research-Based Laboratory Courses

Center for Authentic Science Practice in Education

CASPiE

CASPIE

The partnership includes…

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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***

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

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

NSF workshop report

Exploring the Concept of Undergraduate Research Centers

Research…

- …creates knowledge, communicates discovery, and provides a significant opportunity for the mentorship of students.
- …increases the confidence of students, stimulates their curiosity, improves their communication skills, and enhances their critical thinking and problem-solving skills.
- …can generate sustained and persistent enthusiasm that contributes to the retention of a student either in a specific discipline or even in their undergraduate studies.
- …mentoring can lead to the efficient integration of students into research communities in a way that clearly establishes their career paths.

NSF workshop report

Exploring the Concept of Undergraduate Research Centers

Single faculty mentor-student apprentice model:

- …the limited number of undergraduates that this model can accommodate within the existing faculty capacity.
- …significantly broadening participation in undergraduate research to include freshmen and sophomores will require new paradigms for providing such research experiences within the existing faculty capacity.

NSF workshop report

Exploring the Concept of Undergraduate Research Centers

Single faculty mentor-student apprentice model:

- Faculty time for mentoring undergraduate research and/or curricular reform is limited and expensive, but critical for successful education in chemistry.
- Student course and work schedules often do not allow adequate time for engaging in time-intensive research activities.

CASPiE response: research modules

Research modules in the regular laboratory

- Authored by researchers based on their current research interests.
- Reviewed by faculty involved in implementation.
- Implemented using existing teaching resources.
- Guidance / mentorship using PLTL
- PLTL materials on lab notebook, reading literature, ethics, etc.

Additional dimensions of the main goal

- Increase research capacity at partner institutions.
- Help students develop scientific process skills.
- Increase retention and diversity of students in the sciences.
- Increase the numbers of students carrying out undergraduate research.
- Change faculty and student attitudes about what students are capable of.

CASPiE response: research modules

Student activities within a module:

- Gather background information by reading the module introduction and related research articles.
- Work as part of a group (or team) of peers.
- Design and carry out an experiment.

CASPiE response: research modules

Student learning about research:

- Gain laboratory skills with new experimental and instrumental techniques.
- Develop critical thinking skills in aspects of experimental design.
- Experience disseminating results in an appropriate manner (report, poster, and/or journal article).

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

Placing the Modules in Curricula

- Two options:
  - 1 mod/sem – plus additional experiments
  - 2 mod/sem – CASPiE only
- Certain skills are assumed
  - CASPiE modules only target semesters 2, 3, 4
- CASPiE modules teach some fundamentals – but they are taught within the framework of the research project.

Research Modules to Date

Topic	Semester[a]	Status
Ion sensors using surface protection/deprotection	2, 3	ü
Antioxidants in foods	2	ü
Solid-phase organic synthesis	3, 4	ü
Band-gap tuning of ZnO_x films for solar cells	1, 2	ü
The enzyme system in dairy products	4	ü
Lipids and fatty acids	3, 4	ü
Biodiesel from waste fats	3, 4	Editing
Small molecule antiviral drug discovery	3	Editing
Analysis of NO_x from bio-derived diesel	3	In preparation
Soluble nanopolymers for proteomics	4	In preparation

[a.] The semester for which the module is targeted, of the first four semesters of college (1-2 in the first year, and 3-4 in the second year). Instructor discretion determines exactly which semester of their own course is most appropriate.

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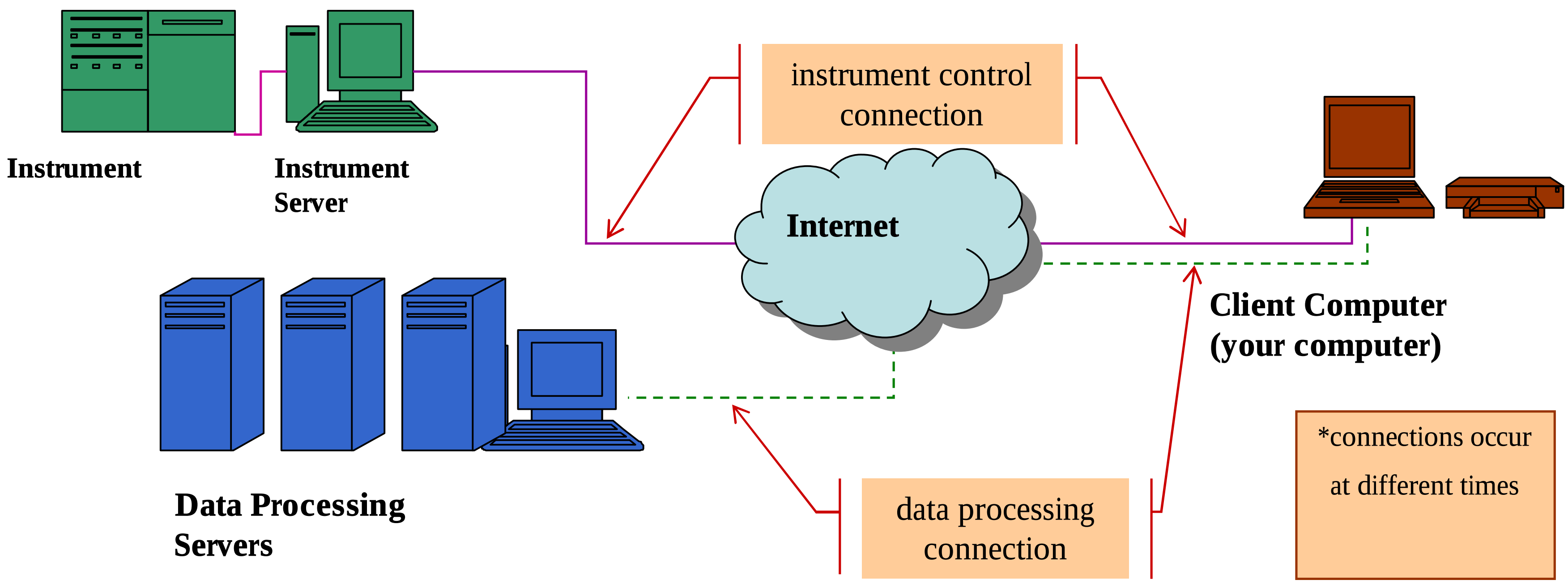
Preparing to Use the Modules

- Obtain equipment and materials listed in module
- CARRY OUT THE MODULE
- Prepare TA's for the new format
  - Review the grading rubrics with them
- Share the grading rubrics with your students
- Have PL's and TA's CARRY OUT THE MODULE
- Plan in advance for research reports or presentations students will do as final report.

The CASPiE Model for Instrumentation

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

Instrument Network Diagram



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

Traditional Peer-Led Team Learning

- Groups of 6-8 students meet weekly (2 hours) to work as a team on problems related to lecture material
- A peer facilitates each team
- No answer key
- Implemented successfully across science and math fields

www.pltl.org

PLTL in the Lab – CASPiE Model

- Students work in teams of three in lab
- Each peer leader facilitates two teams of three in workshops
- PLTL groups help to create a research group environment
- Peer leaders NOT involved in curriculum development or grading

Workshop Sessions

- 10-15 minute discussion of the lab
- 45-50 minute workshop activity:
  - One central idea per workshop
  - Designed to be highly interactive
  - Designed to introduce students to information they need for laboratory research in general
  - Normally, no formal avenue by which students are taught these skills, but acquired through interaction with their research group in a traditional research experience.

CASPIE

Phytochemical Antioxidants in Foods

(Dr. Jay Burgess, Foods & Nutrition, Purdue University)

- This module provides information on food, nutrients, and antioxidants and their relationship to health.
- Students learn about phytochemicals and the chemical characteristics that make them good antioxidants.
- They use a variety of techniques to extract antioxidants from foods and analyze their antioxidant capacities (for example: UV/Vis, HPLC).

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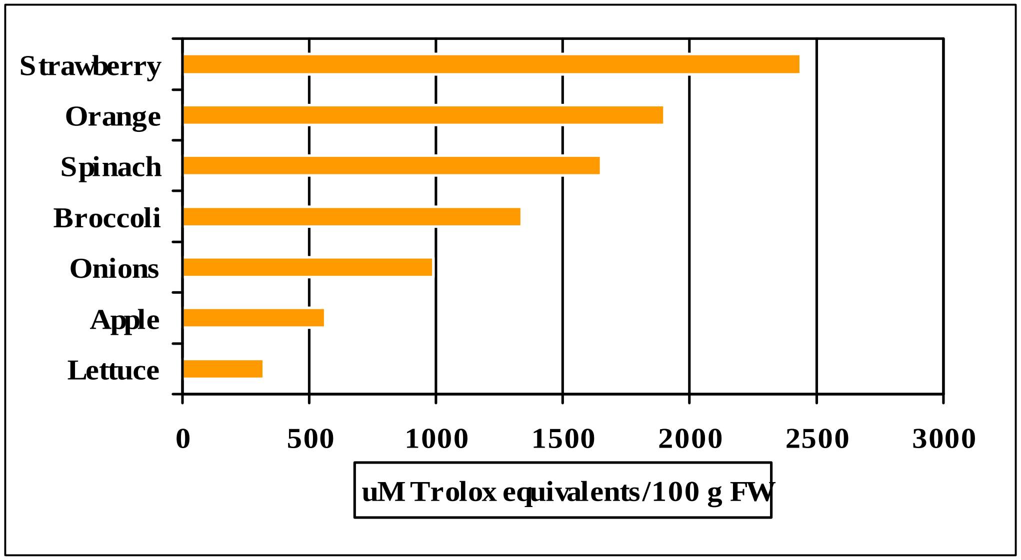

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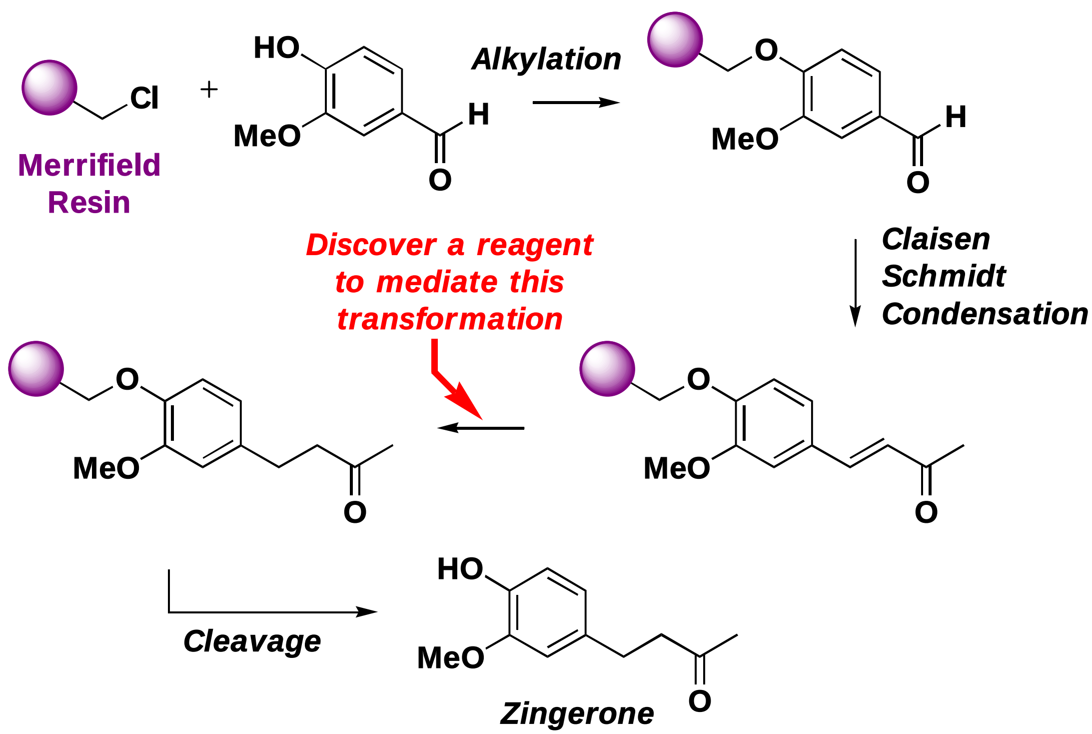
Solid Phase Synthesis of Zingerone

(Dr. Duncan Wardrop, Chemistry, U of IL at Chicago)

- The module provides a comparative study of solid and solution phase chemistry for the reduction of alkenes.
- Structural analysis is a key component: IR/Raman spectroscopy is the primary analytical technique.
- Students also perform on-bead mass spectrometric analysis, elemental analysis, quantitative back titration, and qualitative color tests.

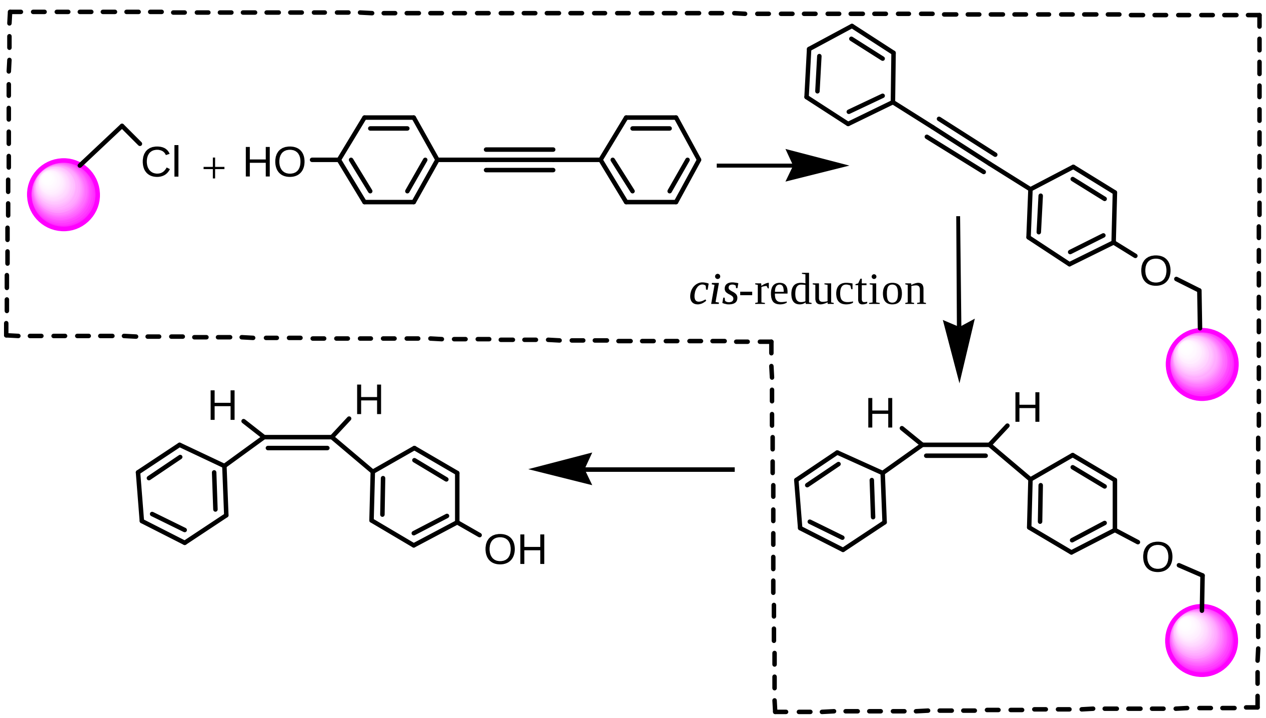
Solid Phase Synthesis of Zingerone

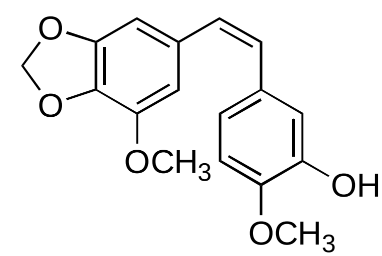
- Investigations in module development



Solid Phase Synthesis of Zingerone

- Extension to new research questions





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Implementation Record to Date

Semester	#schools	#students	#modules
Sp 05*	2	72	3
Su 05*	1	7	3
F 05	2	66	3
Sp 06	8	215	5
F 06	3	184	3
Sp 07	10	787	5
F 07	5	206	4
Sp 08	8	939	4
F 08	4	180	3
Total	11	~2680	

*** Pilot**

Review of Evaluation Results

The following contains information and analysis contributed by Gabriela Weaver, Cianán Russell, and the Evaluation and Assessment Center of Miami University in a project under the direction of Kate Scantlebury of the University of Delaware.

Data Collection for Evaluation

	pre-survey	post-survey	interview
UG participants	X	X	(X)
UG non-participants	X	X	(X)
peer leaders		X	(X)
TA's		X	(X)
instructors		X	X
module authors		X	X

(X) = subgroup was sampled

Evaluation Instrument

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

Factor	Item Number	Cronbach Alpha
1. Interest in Chemistry/Science	17, 18, 19, 20, 21	0.927
2. Real Life and Science	10, 22, 23, 26, 28, 29, 30, 32	0.893
3. Authentic Scientific Lab Practices	5, 7, 8, 9, 11	0.853
4. Perceptions of Learning through Laboratory	12, 13, 14, 27, 31, 34	0.822
5. Belief in Chemistry Knowledge	6, 15, 16	0.788
6. Collaborative Learning in Courses	2, 24, 25R	0.574

Rasch analysis to get a single measure

- "Interest in Chemistry / Science" factor.

Question	Mean	s.d.
17. The lab experience in this chemistry course has made me more interested in chemistry.	2.80	1.51
18. The lab experience in this chemistry course has made me more interested in science.	3.20	1.51
19. The lab experience in this chemistry course has made me more interested in a science career.	2.80	1.44
20. The lab experience in this chemistry course has made me more interested in earning a Masters degree in a science field.	2.45	1.36
21. The lab experience in this chemistry course has made me more interested in earning a Doctoral degree (Ph.D.) in a science field.	2.50	1.36

Data from Purdue "participants," Spring 2006

Advantage of Rasch

- Linearization of results: a psychometric measuring stick.
- Data refined over time.
- Factor scores can still be obtained from absent answers.
- *Ready detection of items and individuals that do not fit the linear model.*

Disadvantage of Rasch

- Measuring stick does not answer the question “what is tall?” and “what is not?”
- Explicitly less sensitive to the extrema, since a good factor samples main part of population thoroughly. *
- May be vulnerable to systematic error (everyone standing on a box).*

* Also problems with normal Likert analysis. Racsch may minimize these.

CASPiE

	2006-7		2008-9	
	Participant	Non-Participant	Participant	Non-Participant
Number	611	680	181	348
1. Interest in chemistry / science	48.95 / 42.17	47.83 / 42.10	56.75 / 57.84	47.71 / 42.86
2. Real life and science	50.40 / 49.08	49.41 / 46.94	54.91 / 59.84	51.00 / 47.28
3. Authentic scientific lab practices	49.13 / 53.74	50.18 / 47.12	54.03 / 67.66	50.47 / 49.60
4. Perceptions of learning	50.23 / 49.72	49.72 / 47.40	55.58 / 55.52	50.21 / 49.13
5. Belief in chemistry knowledge	54.32 / 52.18	52.07 / 49.49	61.46 / 63.09	54.26 / 51.51
6. Collaborative learning	57.75 / 58.88	59.99 / 59.09	55.68 / 58.49	58.77 / 58.49

Interest in Chemistry / Science

- For 2006-7 there was a decrease in this factor for both participants and non-participants.
- In 2007-8 the decrease only occurred for non-participants.
- There was a significant dependence for the pre / post change in this factor depending on whether someone did a CASPiE module.

Real Life and Science

- For both years, there was a dependence on the change in this depending on whether someone did a CASPiE module.
- The score for CASPiE participants either was level (2006-7) or increased (2007-8).
- The score decreased for non-participants for both years.

Authentic Scientific Lab Practices

- For both years, there was a dependence on the change in this depending on whether someone did a CASPiE module.
- The score decreased for non-participants for both years.
- The score for CASPiE participants increased in both years, in 2007-8 by fully 13 points.

Learning through Lab

- There was no effect of participation on this factor in either year.
- In 2007-8 CASPiE participants did show a higher score at the start and the end of the course.

Belief in Chemistry Knowledge

- There was a decrease in this value for both groups in 2006-7, though there was no effect of participation.
- In 2007-8 there was again a decrease for non-participants
- In 2007-8 there was an increase for participants.

Comparison of Inquiry, Traditional and CASPiE Curriculum Models

	A-R	B-R	C-R	D-R	E-R	A-T	F-I
Survey participants	257	23	44	19	-	223	333
Interview participants	7	9	7	8	5	10	9

X-R is X university, research curriculum (CASPiE)

-T is traditional curriculum

-I is inquiry curriculum

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%**
Inquiry	**0%**	**44%**	**11%**	**44%**
Research	**0%**	**42%**	**8%**	**50%**

Comparing Inquiry/Traditional/CASPiE

Changes in ability to describe 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%**
Inquiry	**56%**	**33%**	**11%**	**0%**
Research	**14%**	**39%**	**4%**	**43%**

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
Traditional	**50%**	**30%**	**20%**	**70%**	**20%**	**10%**
Inquiry	**45%**	**33%**	**22%**	**22%**	**67%**	**11%**
Research	**47%**	**32%**	**21%**	**0%**	**34%**	**66%**

CASPiE

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.”

Instructor Views

- All five instructors said implementing the CASPiE labs was more challenging primarily because they required more time and effort from the instructors.
- Also, more challenging because it was a different experience for the students.
- All five instructors indicated that they would implement CASPiE again.
- Instructors described students as being frustrated with the CASPiE labs at first, as it was a new approach from what they were used to, but that over time students adjusted and tended to view the experience as a positive one.

Instructor Quotes

- “They whined and complained for the first few weeks, but we did the antioxidant module and the different groups were picking their different foods, and they were excited about doing that.”
- “The modules are written so that it’s much more structured early and much less structured later, but that still doesn’t mean that this isn’t a big change from the kind of ‘cookbook’ labs that the students are used to working with.”
- “It [the idea of research] is very important because it gives students kind of the end of the rainbow type of goal, that what they’re doing is going to be meaningful to the person who designed the research. I think that element is what creates novelty and interest in the course.”

TA Comments

- “I think that for the people that are going to decide to study chemistry…it’s going to be good. Yeah, I would have liked to have something like this [CASPiE] because it [would] help me decide what I’m going to do with my future as a scientist.”
- “I think it [CASPiE] is a wonderful thing. I actually wish that when I went to [student’s undergraduate institution] that they had something like that just to prepare [me] for what it is going to be like to do research that you don’t know.”

Additional Data Being Collected

- Continued analysis with factor analysis, and qualitative analysis of interviews
- Longitudinal data
  - Participation in additional research
  - Retention in science major
  - Graduation
  - Performance in other science classes
  - Transfer rates (for 2 year college students)
- Learner characteristics: novice to expert

What are we disseminating?

- The product of CASPiE is the *model*, i.e. this approach to laboratory learning
- New modules are supported through module development process
- The instrumentation network is a resource to supplement the model, but model does not rely on it

CASPiE

The Center for Authentic Science Practice in Education

September 16, 2004 - 9:49pm

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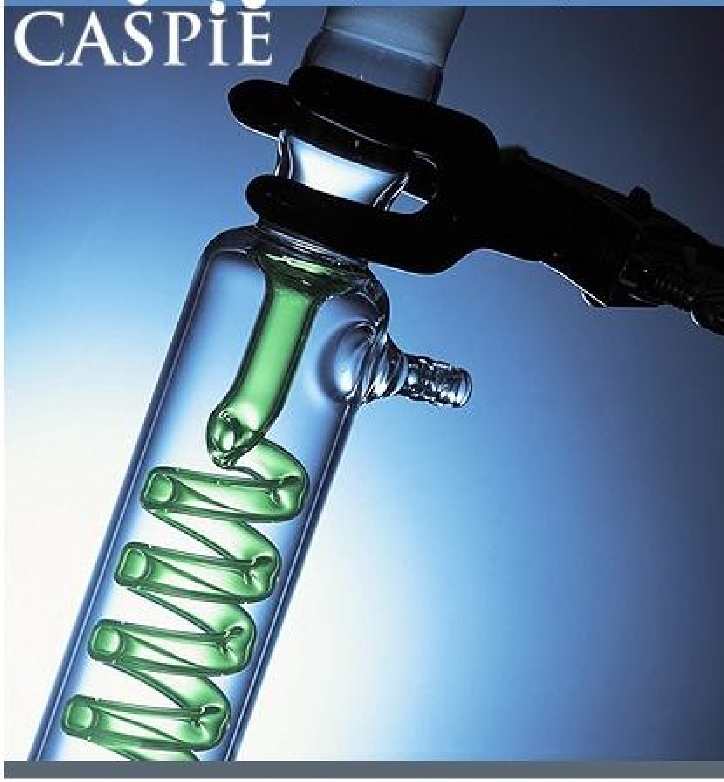

The Center for Authentic Science Practice in Education

Is it possible to effect a renewed interest in the physical sciences by including more research experiences in the educational process, especially early on when many students are making or adjusting their choice of majors? Can programs be designed that are especially suited to retaining women and minorities as well as other segments of the undergraduate population?

Overview

The **Center for Authentic Science Practice in Education (CASPiE)** is a multi-institutional collaborative effort designed to address major barriers to providing research experiences to younger undergraduate science students.

Our Goals

CASPiE will take advantage of the complementary strengths and needs of its different partner institutions to develop a program that will:

1. Provide first and second year students with access to research experiences as part of the mainstream curriculum. Go to: Course Materials

2. Create a collaborative, "research group" environment for students in the laboratory. Go to: PLTL

3. Provide access to advanced instrumentation for all members of the collaborative to be used for undergraduate research experiences. Go to: Instrument Network

4. ... s to that their own research ... ese institutions can participate in

www.caspie.org

5. ... engaging for women and ethnic minorities and appropriate for use at various types of institutions, including those with diverse populations. Go to: Evaluation

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