Outline

I. Background
II. Defining the problem
III. Computer Assisted Learning Method
IV. Initial Results
V. Challenges associated with supporting and spreading CALM
V. Summary
VI Career advice

Acknowledgments

• Students who used CALM over the past 10 years.
• Faculty in chemistry (both IU and elsewhere) and physics who incorporated CALM into their courses.
• R. Althauser, Dept. of Sociology, Indiana University

R.T. deSouza, Indiana University
*Careers in Academia* seminar UIUC
We are in a growing crisis!

Your ability to teach is determined by:

• The ability of your students
• Their preparation

Only 26% scored high enough on the science test to indicate they are likely to succeed in college biology.

R.T. deSouza, Indiana University
Careers in Academia seminar UIUC
My Background

• Research active faculty (Nuclear chemistry/Physical Chem.) in a research intensive dept.
  – Research group of ~6-8 graduate students, postdocs, and undergrads
  – Teach 1 course/semester; freshmen + sr. undergrad/grad
• Post-doc at Michigan State Univ.- NSCL when CAPA was first developed.
• Asst. Prof at Indiana, Bloomington since 1991; Assoc Prof. 1997-2000; Full Prof. 2000 – present
• First taught in general chemistry program in 1995
• Began development of CALM in 1996
Background

Each Spring for 6 years I taught the second semester of our main freshmen chemistry sequence (450-600 students).

*How does one assess the understanding of the students on a regular basis?*

It is not just the problem of a large class, one has the same problem with a class of 20. Of course in a small class one claims that by asking the class questions in-class one can assess their understanding.

*What about the students who refuse to answer questions in class?*

**Assertion** —

The moment you sacrifice the one-on-one interaction you have lost something. That is why students participating in undergraduate research have such an unique experience.
Problems in teaching a group of any size –

• many of the best students are not sufficiently challenged
• culling the “best” students into an honors section doesn’t solve the problem.
• In-class exams do not provide an environment to fully challenge the capabilities of every student.

Part of the solution is to increase the accountability of students in their out of classroom time.

Homework/Exercises with feedback

Third International Mathematics and Science Study (1995)

In the final year of secondary school (twelfth grade in the U.S.), U.S. performance was among the lowest in both science and mathematics, including among our most advanced students.

R.T. deSouza, Indiana University

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WWW based instruction has increased dramatically in the past 5-7 years.

- Faculty placing notes, exercises on the Web (static, no interaction).
- Interactive tutorial and mastery programs (among the best)
  a) CyberProf, Univ. of Illinois; physics and chemistry
  b) CAPA, Michigan State University; physics and chemistry
  c) OWL, University of Massachusetts, chemistry

The educational materials developed by publishers is of substantially poorer quality (intellectual content). The initiative must be taken by the universities!

Accessibility—a rapidly changing landscape
- A recent study showed that “more than half of Americans now had access to the Internet from home.”
- Release of Internet access network devices e.g. WebTV, iPAQ, etc.

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Original Motivation behind C.A.L.M.

• Math and science are problem solving subjects ➔ students need to solve questions on a regular (sustained) basis to help internalize the concepts.

• The best feedback is immediate. Not only is this a statement about our instant gratification society, but education research demonstrates this fairly conclusively.

• students should have individualized questions to encourage symbolic communication (enhances cooperative learning).

• the faculty member should have “instant” feedback about the performance of a class or individual on a particular topic.
How CALM came about

• 1993 (spring) co-taught gen chem for the first time
• 1994 (spring) introduced weekly, graded homework (8-10 questions)
• 1995 (spring) increased the percentage of homework graded
• 1995 (summer) developed CALM structure
• 1995 (Fall) CALM used on a voluntary basis in colleagues course
• 1996 (spring) used CALM as “required” as an integral part of my course
Basis for C.A.L.M.

“Computers are great for three things: Storing data, performing calculations, and making decisions.” - RdS

1. WWW based ⇒ a) allows widespread dissemination of material  
   b) facilitates accumulation of group/class statistics.

2. Questions are individualized (semi-random, algorithmically generated). ⇒ a) Encourages symbolic communication  
   b) reduces copying/cheating.

3. Based on a Socratic pedagogy ⇒ Encourages logical thinking

The computer allows us to “simulate” one-on-one interaction.
Features of the program

- Each student is presented with an individualized, semi-randomly generated question. All questions are algorithmically generated which allows the student immediate feedback about the correctness of their response.

- A student can make repeated attempts to solve the question without penalty – which encourages learning.

- A student can request a new question to ensure comprehension of a particular topic.

- All interactions of students with the program are logged so a teacher (or parent) could examine the performance of a student or a group of students.

- A ‘testing mode’ also exists in which students get only one chance to answer the question presented.

- CALM is available for both in-school and at home utilization.
CALM is a Web-based tool to assist students in learning.
CALM is based upon a Socratic pedagogy.

- Each question represents a series of interactions between the student and the system.
- In response to an incorrectly answered question, the student is presented with a new leading question.
CALM is a **learning tool** and allows a student an unlimited number of tries to solve the question presented.

CALM can also **restrict the number of tries** available to a student in answering a question.

“Learning” = homework

“Testing” = Quizzes and Exams
Access to CALM is organized by course and each student logs in at the beginning of a session.
Navigation is achieved by an intuitive menuing system that easily allows students to see assigned questions and their progress to date.
Multiple Choice Questions

CALM includes the ability to present simple, **dynamically generated**, multiple choice questions. This means that **different students can get different questions**. It is not just that the order of the answers is scrambled, but the choices can be different!

Which one of the following substances is a **pure compound**?

1. ○ cement
2. ○ sodium
3. ○ ethanol
4. ○ hydrogen
5. ○ sulfur

**correct answers appear for faculty in bold!**

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In multiple select questions, students are confronted with the possibility that multiple answers might be correct.

Correct answers appear for faculty in parentheses!

Multiple Select Questions

Given the following molecules:

- SOF$_4$ (Trigonalbipyramidal shape)
- PF$_5$ (Trigonalbipyramidal shape)
- SnF$_6^{2-}$ (Octahedral shape)
- SiCl$_4$ (Tetrahedral shape)

- None of the above.

Which of them are associated with the depicted shape?

Trigonalplanar shape

Push me! to continue.
Matching Questions

With *matching questions*, students can be exposed to new vocabulary or concepts. While one can imagine this question used to teach scientific vocabulary, it can also be used to teach more general non-scientific concepts.

Flags Description of hint flags
- A non-case sensitive word match

Push me! to continue.
Questions in CALM can be complex, requiring multiple **numerical calculations**. They allow the student to answer the entire question at one time or can lead the student through the solution.

A student carries out the following P-V experiment.

**Stage 1**: Starting with 2.80 mol of an ideal gas at $P = 0.80$ atm and $V = 1.80$ L she performs an isothermal expansion to a volume of 4.5 L.

**Stage 2**: Keeping the volume constant she then increases the pressure to 1.20 atm.

**Stage 3**: She then compresses the gas isothermally to the initial volume of 1.80 L.

**Stage 4**: Maintaining a constant volume she decreases the pressure to its initial pressure of 0.80 atm.

These changes are represented by the following P-V diagram:

![P-V diagram](image)

Calculate the change in internal energy ($E$), work ($w$), and heat ($q$) accompanying each stage. Also, calculate $\Delta E$, $q$, and $w$ for the full cycle.

<table>
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<tr>
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</table>
Questions in CALM can also be graphical stressing the relationship between different objects or quantities.

Another example of the same type of question would be to present the student with a graphic of the human anatomy and ask them where the hypothalamus is located. Alternatively, one might show them a map of the world and ask them where Germany is located.

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CALM also includes questions that test the ability of students to understand spatial relationships.

Such **advanced graphical questions** are dynamically generated in CALM.

R.T. deSouza, Indiana University - Careers in Academia seminar
Faculty are also able to present students with essay questions. These questions are not random and require manual grading by the instructor. Nevertheless, CALM facilitates the logistical aspects for both the student and the instructor.

R.T. deSouza, Indiana University

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<table>
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<tr>
<td><strong>Example Essay Question - Student Version</strong></td>
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The general public is exposed to nuclear radiation from a variety of sources of both natural and man-made origin. Because exposure to nuclear radiation involves health risks, some people argue that the only safe level of radiation exposure is zero. If similar reasoning were applied to our use of the automobile, the safe speed for driving would be substantially less than most posted speed limits (ideally zero).

Discuss how we arrive at levels of acceptable risk in our lives, making reference to the areas of nuclear radiation and transportation.

Can you think of other areas where a similar contradiction arises?

Discuss how one might deduce an appropriate level of risk for an activity that would be harmful.

**Grade:** Not Graded

---

Permissible Levels of Exposure

The US National Council on Radiation Protection and Measurement gave expression to the theoretical resolution of this human dilemma by articulating the implicit reasoning behind subsequent radiation protection standards development:

A value judgment which reflects, as it were, a measure of psychological acceptability to an individual of bearing slightly more than a normal share of radiation-induced defective genes.

A value judgment representing society's acceptance of incremental damage to the population gene pool, when weighted by the total of occupationally exposed persons, or rather those of reproductive capacity as involved in Genetically Significant Dose calculation.

A value judgment derived from past experience of the somatic effects of occupational exposure, supplemented by such biomedical and biological experimentation and theory as has relevance. This is now an internationally accepted approach to setting standards for toxic substances when no safe level of the substance exists.

In short, this elaborate philosophy understand the fact that there is no safe level of exposure to
Faculty (or associate instructors) can view the performance of students in the class via the Web.

Credit can be awarded for a particular question on an individual basis.

---

### Grades for Course Calm 103

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**R.T. deSouza, Indiana University**  
*Careers in Academia* seminar UIUC
Monitoring student performance

Question Distribution:

Textual Distribution

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Monitoring student performance

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</table>
Tools for Question Development

All question development is Web-based.

The CALM question editor is a powerful tool for authoring content. Along with ‘Wizards’ it facilitates content development.

Within a two day workshop, teachers become familiar enough with the tool to develop their own CALM questions.
In constructing a course, faculty can select questions from a database of available questions. The database in CALM is keyword searchable which simplifies the process of ‘constructing a course’ for the instructor.

R.T. deSouza, Indiana University
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CALM also includes a course management tool which allows faculty to post grades for CALM and non-CALM based assignments.

This allows students and parents to view real-time progress in a course.

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IV. Initial Results (My motivation to keep going)

“Fuzzy-Wuzzy” results (anonymous survey following Spring 1997)

1. Students increased time spent studying for course from <2hr/week to ~4 hrs/week.

2. Do you find CALM useful in helping you learn the material presented in the course?
   a) extremely useful 37%
   b) very useful 35%
   c) moderately useful 19%
   d) slightly useful 5%
   e) not useful at all 3%

3. 76% said that it was a “good” or “very valuable” tool in a differently worded or arranged question.

These initial self-perceived benefits were encouraging!

“The most positive aspect of CALM is that you can immediately find out whether or not you got your question correct. This enables a person to know whether or not she is approaching the problem in a correct way.” – Anonymous student

R.T. deSouza, Indiana University

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Analysis following Fall 1997 (R. Althauser)

Multivariable linear regression analysis:
1. \( \text{CALMPTS} = f(\text{SATACT}, \text{CHEM PLACEMENT}) \)
2. \( \text{EXAM SCORE} = f(\text{SATACT}, \text{CALMPTS}) \)
3. \( \text{EXAM SCORE} = f(\text{SATACT}, \text{CALMPTS}, \text{CHEM PLACEMENT}) \)

\text{SATACT} : \text{measure of math skill prior to course.}

\text{CHEM PLACEMENT} : \text{Chemistry placement exam assesses prior knowledge of chemistry.}

\text{EXAM SCORE} : 4 \text{ in-term exams (25 pts each.)} + 1 \text{ Final (50 pts.)}

\text{CALMPTS} : \text{Points accumulated in CALM, 1 pt./question correctly answered; 100 questions normalized to 10 pts.}

Sample : Students who missed no more than 2 exams

\[ 511/681 \ (77\%) \]

After correcting for differences in math ability and prior chemistry knowledge, CALM performance is a strong predictor of Exam scores. One standard deviation in CALM corresponded to the difference of a letter grade!

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Expanding the impact of CALM

- 1997: CALM developed for 2nd semester gen. chem.
- 1998: Extended to 1st semester gen chem
- 2000: Pre-lab exercises
- 2003: CALM in HS
- 2005: Physics
- 2006: Limited funding from Dept. of Education

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Limited funding from Dept. of Education
How did this expansion happen?

• I.U.: Chemistry and Physics (conversations/demos with colleagues)

• Other Colleges and Universities: Morehead State, Cal State Fesno (former IU students/postdocs, posting on the Web, presentations at BCCE)

• High Schools (working with established programs—ACP, individual contacts, Web)
Our Goal

Impact the level of HS science education in Indiana

• improve the performance of Indiana high school students, especially under-represented minorities, in science.

• make Indiana HS teachers more effective in teaching their disciplines (network teachers with university departments; network teachers together).

Approach

Develop a collaborative environment between IUB and Indiana HS teachers in which Web-based learning tools developed at IUB could be disseminated for use in Indiana high schools.
Expanding CALM to HS

- Provides *professional development of HS teachers* in their discipline
- *Networks IU with HS teachers and teachers with teachers*
- Facilitates the *dissemination of high quality standards based/aligned materials*
Participation in CALM is geographically widespread across Indiana.

Presently ~3000 HS students in ~50 HS are using CALM
I estimate present cost of CALM at ~$80-100k. This cost is borne by a tenuous patchwork of support from the Department of Chemistry, College of Arts and Sciences, Bloomington chancellor, Campus Writing Program, and SBC/Ameritech and US Dept. of Education

**Estimated Annual Budget**

- **Development (content)**
  - 1 programmer: $40K
  - Teacher Summer Stipends (15-20 teachers): $10K

- **Dissemination (Workshops)**: $5k

- **Assessment**: $10K

- **Equipment**: $10K

**TOTAL**: $75k

Departmental contribution of ½ FTE: $20k

R.T. deSouza, Indiana University

*Careers in Academia* seminar UIUC
V. Summary

• We have developed and implemented in a large class environment a WWW based learning tool (C.A.L.M) which provides algorithmic generation of individualized questions for students based upon a Socratic pedagogy.

• Student performance with this tool correlates strongly with exam performance.

• This tool has a great deal of potential for: impacting student performance, improving teacher professional development, networking HS with colleges/univ., student recruitment.
VI. Career advice

• Determine what you are passionate about
• Determine what you are good at
• Know the environment that you are getting into
• Don’t underestimate the resources necessary to achieve your goals
• Don’t over-estimate the problem (or you will never start the journey)
• Work hard for the immediate result but take the long view
I talked about how I use this program at the workshop I was giving at the National Science Teachers’ Association Convention held here in Indianapolis this year. Those who heard it were so impressed that I was invited to give a talk at a breakfast for Chemistry Teachers of Indiana at the Hoosier Science Convention in February, 2005.

I love the program and my students love it. I have attached some of the letters my students wrote expressing their thoughts and feeling about the program. It is user friendly for the teacher and the students and saves me tons and tons of time. Time is what I never have enough of. This program also enables me to see how my students fare with other students as they are all trying to do the standard problems. I was amazed to see how responsive and motivated they have become since the program was first introduced to them. I have COWS (Computer on wheels) in my class and we sometimes do class work also. I have the problems assigned; they each have a different variation of the problem and that eliminates copying or cheating. Once, I gave a quiz using CALM. It worked and makes grading so much easier. My students mostly do homework on CALM.

I hope we get funding for this excellent program. It will be great if we can offer on line tutoring.

-- Ruby Sing, Arlington High School, IPS

R.T. deSouza, Indiana University
Careers in Academia seminar UIUC
Students seem to prefer CALM over the old-fashioned, pencil-and-paper method. It is a great way to incorporate the use of technology in the classroom. (CALM) eliminates the possibility of cheating and forces students to actually read the problem. CALM is wonderful thing. Students seem to like it. It makes teachers’ lives a bit easier. Best of all, it is free. I truly hope that the State of Indiana will begin funding CALM because I would cringe to think that such a valuable educational tool might vanish due to lack of financial support.

-- Jennifer Fields, Chemistry Teacher Frankton Junior/Senior High School
My students report that they are learning by using CALM. I have observed many good discussions among students on “how” to do a particular problem. I am happy to report that my students are performing better on assessments this year than they did last year, and I have to attribute this to their exposure to the problems that I assign them on CALM. Students no longer have a choice in my classroom—they have to learn how to approach problem solving. In addition, CALM has taken away the taboo practice of students helping students. Now that students receive unique homework problems, they are free to help one another lean the concepts rather than sharing answers.

I have begun using CALM as a method of remediation. The database of questions on CALM for physics needs more funding to be developed fully, but I have begun using the CALM physics portion as a remediation tool for my physics students by writing my own questions for the physics database. Students who do not pass my in-class assessments are given the opportunity to sign up for an on-line “retake” on CALM. Students have responded very positively to this experience, and I’m seeing all demographics of students benefiting from being able to go back and relearn material. I can be certain that my students using this remediation are really learning when they complete the on-line CALM retake assessment.

If the state of Indiana is looking to improve student learning in sciences, full support of this ingenious system is a necessity. The CALM system developed at IU Bloomington is truly cutting-edge and distinguishes IU as a leader in teaching science world-wide. CALM is the first system of its kind and needs full support.

R.T. deSouza, Indiana University

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Brian White, National Board Certified Teacher, Lawrence North High School
I have been teaching high school chemistry for over 30 years and have never found new technology that is as helpful to my students as CALM. …it has numerous advantages over the old paper work assignments.

- greatest advantage is that students receive instant feedback.
- With CALM, everyone gets their own problems so the sharing that takes place is talk about how to do the problems. This is peer teaching which has been shown to be an extremely effective means of learning.
- by receiving a grade report I know which questions were difficult for the students. I can use this information to improve my classroom instruction and to re-teach certain topics.

I am hopeful that more money will be made available to the CALM administrators such that they can develop a larger database of questions suitable for high school chemistry teachers.
Three years after offering CALM to Indiana HS

Fall 2004:
38 Schools participating
41 Teachers using CALM
100 Courses listed: 96 Chemistry, 3 Phys, 1 Biology
2965 Students enrolled in these courses

Growth --
2002 trained 3 teachers
2003 trained 13 new teachers
 trained 2 new teachers through peer instruction (BHSN)
2004 trained 21 new teachers in person
 trained 2 new teachers using web tutorial documents

R.T. deSouza, Indiana University
Careers in Academia seminar UIUC
Increasing access, so little organized content.