

Of Special Interest

# Report On “The MATCH Program: Integrating Student Learning in Science and Math”

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*Dr. Wink opened the seminar by stressing a leading point of the MATCH program: “Change students during the first semester or you can’t change them at all.”*

The inability to integrate mathematics and chemistry continues to plague science and math undergraduates. General chemistry students often lack the ability to apply the mathematics they already know to problems given in their chemistry classes, and mathematics students often stumble through word problems. In response to this prevalent compartmentalization, Dr. Donald Wink created a program at the University of Illinois at Chicago to break down illusory mental borders between mathematics and chemistry. Strategically, he accomplished this by creating a single course where students work in teams to answer word problems; by stressing the effective use of graphing calculators

“The MATCH Program. Integrating Student Learning in Science and Math” by Donald Wink was presented at the “Day 2 to 40” workshop symposium held May 10–11, 1997. The two-day event was held in the Willard H. Dow Chemical Sciences laboratory building on the central campus of The University of Michigan in Ann Arbor, Michigan. Each of the articles that comprise this issue was written by one of the group of reporters whom I asked to attend each session to take field notes and then follow up with the session leader and participants afterwards.

—Brian P. Coppola, Proceedings Editor

in this course; and by giving significant, physical meaning to the symbols used in equations. During Dr. Wink's "Integrating Student Learning in Math and Science" workshop, attendees experienced these three techniques first-hand when they worked through mathematics-based chemistry problems (and vice versa) together.

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## Seminar Chronology

### *Part One: Coordination of Math and Science and Implementation Strategies (35 min)*

1. Introduction (10 min): Dr. Donald Wink's background and goals of this "2-to-40" workshop.
2. Description of MATCH Program and Goals (5 min): Outline of Dr. Wink's integrated MATH and CHEMISTRY program (MATCH) and its goals.
3. Discussion of General Problems (20 min): Raised general issues with teaching math and science. For example, students can skip math problems and still get B's, and students usually fail to realize the physical meaning of equations.
4. Sharing of Attendee's Backgrounds (10 min): Each attendee described particular teaching challenges at his or her institution.
5. MATCH Organization Logistics (20 min): Description of course structure and lectures.

### *Part Two: Hands-on Graphing Calculator/Computer Modeling Workshop (50 min)*

1. RasMol<sup>1</sup> Software (25 min): Attendees explored the RasMol molecular-modeling program and discussed adapting it for use at their institutions.
2. Graphing s Orbitals (25 min): Attendees graphed equations for the hydrogenic 1s orbital using a graphing calculator and the wave equations from a textbook.

## Introduction

Dr. Wink opened the seminar by stressing a leading point of the MATCH program: "Change students during the first semester or you can't change them at all." Allowing students to learn separate methods for solving mathematics and chemistry problems in

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<sup>1</sup> RasMol<sup>©</sup> copyright 1992,1993,1994 by Roger Sayle [rasmol@ggr.co.uk](mailto:rasmol@ggr.co.uk).

non-MATCH courses complicates further teaching because students must first “unlearn” the old techniques before being able to fully convert to integrated thinking. A conversion to MATCH thinking, however different, is important because science-phobic students can skip word problems and still get B’s in a math course. Overcoming this and similar endemic teaching problems constitutes the core goal of the MATCH program.

### **MATCH Program Goals**

A student who has completed the MATCH program:

- realizes math and chemistry are interlocking segments of a unified science,
- has developed the tools to overcome “word-problem phobia” and can apply these tools to different academic fields,
- and, most importantly, understands the logic and physical significance of math and chemistry phenomena.

The MATCH program reaches these fundamental goals using a teaching philosophy based on averting student difficulties before they arise.

### **MATCH Philosophy (5 Fundamental Ideas):**

#### *1. Change Students during the First Semester.*

The MATCH program has been offered both first and second term, with considerably more success the first term. At the seminar Dr. Wink pointed out that, “Students come in for one course and whatever they see this first time is what they plug in as a definition for chemistry. If you get them in the first term you change the rest of their life.” Many attendees agreed that they had encountered this problem of re-educating students who had already learned to mentally divide scientific disciplines.

#### *2. Informal Lecture Time*

By removing the formal structure of the typical lecture class, students and teachers can use the time to practice problem solving. This has the benefit of forcing the students to solve their problems before leaving class; therefore, it saves them from common “mental roadblocks” when working at home.

### 3. Merge Topics

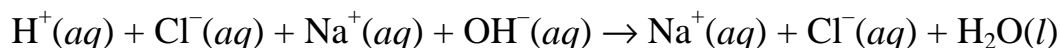
Because many students enter the program with more confidence in their ability to learn chemistry than mathematics, MATCH mixes mathematics and chemistry topics. Strategically, this allows students to overcome mathematics phobias by using their desire to learn chemistry as motivation to explore the mathematics. This also works in the reverse for mathematics students, because they have the opportunity to interact with the physical meaning of their somewhat abstract equations.

### 4. Graduate-Student Instructors Spend Time Working Problems with Students

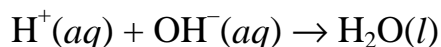
Because some graduate-student instructors come from mathematics backgrounds and some from chemistry backgrounds, MATCH brings the students into contact with different viewpoints and problem-solving techniques. By maximizing student exposure to these sources, MATCH guides students to integrate their knowledge into one coherent set of analytical tools.

### 5. Create a Unified Language for Mathematics and Chemistry.

By giving students a mental dictionary that links and explains the two languages, the MATCH program explains distinctions between notations and equations. For example, a typical student linguistic difficulty is that ambiguous words like “cancel” can change meaning depending on their context. “Cancel” implies subtraction in chemistry:



becomes



The  $\text{Na}^+$ 's and  $\text{Cl}^-$ 's “cancel” in going from the complete to the net ionic equation. In the context of mathematics, however, cancel implies division:

$$x \times y / x = y$$

The  $x$ 's “cancel” The mathematics/chemistry discrepancy in notation for exponents also illustrates this point. Chemists often use exponents to symbolize a formal charge:  $\text{S}^{2-}$  and  $\text{Mg}^{2+}$ , but in a similar level mathematics course, exponents are more likely to represent powers of a variable:  $1/\text{S}^2 = \text{S}^{-2}$  and  $X \times X = X^{+2}$

In order to avert potential problems, the MATCH program always gives physical significance to equations used in class. Another way it successfully accomplishes this is by having students represent new ideas with calculators and computers whenever possible.

### **Graphing Calculator/Computer Modeling Workshop**

This type of technology-aided, hands-on visualization forms the cornerstone of the MATCH program. Laptop computers, modeling software, and graphing calculators transform equations to express their meaning in a less abstract manner. For the interactive portion of Dr. Wink's presentation, the twelve attendees split into two groups and worked through some assignments the MATCH program has previously employed. One group explored RasMol, a three-dimensional molecular-modeling program, while the other group graphed the hydrogenic 1s orbital with the aid of a graphing calculator.

#### *Molecular Modeling Software Workshop*

For the first part of the hands-on segment of the seminar, attendees worked out the Cartesian coordinates and connectivity for the atoms in CH<sub>3</sub>F. Next, they entered these into a laptop computer running the RasMol software. This produced a rotating, ball-and-stick image of CH<sub>3</sub>F using the bond lengths and atom positions supplied by the attendees. In effect, it made attendees use knowledge of geometry and chemistry to tell RasMol how to draw the molecule. Dr. Wink explained the benefits of this software by demonstrating its "spectacular effect on fast, colorful computers." An additional benefit is that students can take the software home on disks.

The strongest feature of this type of software is the way it merges physics, calculus, engineering, and chemistry under one interface. Dr. Wink described it as "a way to see concretely something that potentially teeters on the edge of abstract in the students' minds." He also related that students ask two main questions when learning about orbitals: "Where does a radial node come from?" followed quickly by, "What does it look like?" Because of technology-enhanced visualization, students receive pictorial answers to both questions.

### *Graphing Calculator Workshop*

For the second hands-on segment of the seminar, attendees discussed ways they could graph the hydrogenic 1s orbital by using the formulas and graphing calculators that Dr. Wink made available. The familiar (to the attendees) graph of the 1s wave function versus radius took form after they pooled together their knowledge of calculator graphing and chemistry. In hammering out the solution they were forced, in synch with the traditional benefit of peer teaching, to evaluate and describe their own methods of problem solving. During this segment, group members also took the opportunity to discuss why they did or did not teach mathematics and chemistry as integrated topics in their courses and what experiences lead them to that choice. In this way they used peer discussions to find solutions for applying MATCH. Because several attendees agreed with the MATCH program philosophy, the main question for them was not *whether* to implement MATCH, but *how* to implement it.

### **Adaptive versus Adoptive Ideas**

The question of how to implement MATCH philosophy has two types of answers, because content in “2-to-40” sessions splits into two categories: ideas that can be modified for use in pre-existing university programs (*adaptive* ideas), and ideas meant to be directly implemented by replacing a pre-existing program (*adoptive* ideas). While the MATCH program contains answers in both areas, it relies primarily on adaptive methods to reinforce adoptive ideas. The demonstrations from the hands-on section of the seminar were programs Dr. Wink found successful, but they are not the sole viable application of his ideas.

### *Adoptive MATCH Ideas*

The core elements of MATCH philosophy form the adoptive “doctrine.” Principles such as calculator use and group work, cannot be removed from the MATCH curriculum without destroying its particular effectiveness. The five philosophical goals outlined above distinguish the MATCH program from contemporary techniques, and this seminar stressed adoption of some of its basic tenets.

### *Adaptive MATCH Programs*

Some of the more malleable MATCH program segments included the graphing calculator assignments, the informal lecture/discussion structure, and the computer-aided methods to help students intermesh science disciplines. The graphing calculator

workshop proved to be the most effective tool Dr. Wink used to demonstrate ways to adapt the MATCH program. He showed attendees how they could put MATCH into practice by stressing that they talk among themselves and work as groups during this workshop. He encouraged attendees to discuss differences in application techniques based on their different contexts. Attendees then debated the practical merits and drawbacks of each idea in the context of their schools and students.

When attendees from Rice University and Penn State University similarly expressed frustration with students' compartmentalization of chemistry disciplines, such as into thermodynamics and kinetics, many other attendees nodded in agreement. Dr. Michael Doyle (The Research Cooperation) also commented that compartmentalization occurs unless students can visualize the physical significance of equations. In response, Dr. Wink pointed out that the ways teachers conduct information to the students can add the critical mass that breaks down these imaginary mental walls. He reminded teachers to relate everything to "the big picture." "Students are blind, and until you show them the whole elephant they will segment off the different areas."

Flexibility in the lecture/discussion format of the course also provides university-sensitive options. Although UIC rebuilt the lecture into group problem-solving time, universities could also use this time to familiarize their students with the necessary technology.

### **Feedback**

"It was a good workshop in that it provided for some actual hands-on experience of what the speaker was doing. It was also good that he went around the room and allowed people to say who they were and why they were interested in the subject of the workshop. This allowed people to more directly address concerns of others."

"I cannot think of anything that I would use in my own classroom, but can see places where some of the ideas might be applied especially to General Chemistry courses and to those populations who have the most difficulty with mathematical reasoning. What would really be required is for the Mathematics and Chemistry Departments to decide to offer such a combined course."

"More hands-on time, less lecturing, but that is hard to do."

## Conclusion

Through this type of technology-aided teaching, Dr. Donald Wink at the University of Illinois at Chicago developed a successful first-term integrated science and mathematics course. Seeking to dispel perceived boundaries between the disciplines, the MATCH program uses five basic tools: first-term intervention, informal lecture time, merging of topics, graduate-student involvement, and unification of seemingly separate languages. This “2-to-40” session stressed the program’s adaptive abilities in other university settings through attendee participation and discussion. With analogous student participation and discussion, the MATCH program changes student learning for the remainder of their college education.

## Workshop Participants

Donald Wink (Leader, [dwink@uic.edu](mailto:dwink@uic.edu)), Suzanne Blum (Reporter, [sablumz@umich.edu](mailto:sablumz@umich.edu)), Jonathan Irish (Reporter, [irishj@umich.edu](mailto:irishj@umich.edu)), Lisa Bell-Loncella ([kintnert@pitt.edu](mailto:kintnert@pitt.edu)), Scott Best ([best@skynet.chem.psu.edu](mailto:best@skynet.chem.psu.edu)), Michael Doyle ([mduoye@trinity.edu](mailto:mduoye@trinity.edu)), Seyhan Ege ([snege@umich.edu](mailto:snege@umich.edu)), Martha Gash ([mgach@umich.edu](mailto:mgach@umich.edu)), Ester Gibbs ([egibbs@goucher.edu](mailto:egibbs@goucher.edu)), Rebecca Miller ([rmiller@sienahts.edu](mailto:rmiller@sienahts.edu)), Deanna Mitchell ([djmitchell@nwu.edu](mailto:djmitchell@nwu.edu)), Bill Sweeney ([wsweeny@shiva.hunter.cuny.edu](mailto:wsweeny@shiva.hunter.cuny.edu)), Robb Wilson ([rjwilson@umich.edu](mailto:rjwilson@umich.edu)).