LDC *Lately...*

Learning Development Center

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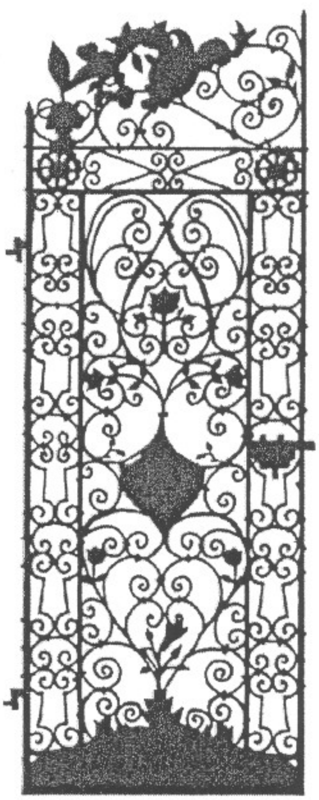
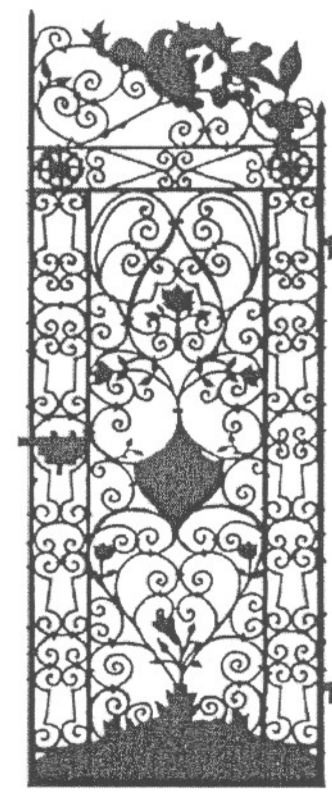
Math Issue



LEARNING MATHEMATICS AT THE COLLEGE LEVEL

At a time when the demand for mathematical skills is growing, when technology has become a way of life, when more female students and minorities are entering the engineering and science fields, when taking advanced mathematics courses in high school increases the likelihood of all students, including high risk ones, to persist toward a Bachelor's degree, mathematical competence is critical for learning and career success. Of the more than 200 college degree programs at RIT, over 75% of them have math requirements for degree completion. Although we expect majors in engineering, computer science, business, and the sciences to rely heavily on mathematics, degrees in social work and criminal justice require at least two quarters of statistics and a non-statistics math course. In addition, some majors in printing, photography, ultrasound, and telecommunications require calculus as well as statistics. Increasingly, students are expected to learn advanced mathematics and its applications to receive a Bachelor's degree from RIT. However, students who enter RIT are not equally ready to tackle college level math courses. Non-engineering and non-science students often come with high school backgrounds that are weak in mathematics, i.e. no more than two years of formal study and typically in only the 9th and 10th grades. There are also students who, while having completed four years of high school mathematics, have done so in very superficial ways, relying more on rote memorization than on conceptual understanding. In spite of average to above average high school math grades, some of these students cannot explain basic algebra concepts, generate formulas, or apply their math knowledge to different situations. This is a national problem, reflected in the 1995 Third International Math and Science Study. Results indicated that U.S. high school seniors, including those in advanced math classes, scored below averages in mathematics of more than half of the participating 21 countries.



The year 2001 brought significant changes in RIT's freshman calculus sequence. The RIT Department of Mathematics & Statistics, after a year of intensive research, implemented three important new ventures:

1) a new approach to teaching the Calculus 251 sequence that includes two additional hours each week devoted to projects and problem solving in small, collaborative groups,
2) placement testing for all Calculus 251 students,
3) a new precalculus course.

In addition, teaching assistants were hired and trained to assist math faculty and students in SMAM 251 and to help staff the COS Study Center that provides math support 9:00 am to 6:00 pm daily. The math faculty of the Learning Development Center (LDC) participated in these new endeavors. They taught the new precalculus course, trained the teaching assistants for the calculus workshops, served on the committee for the Early Alert Intervention System, and were referral resources.

We are devoting this issue of *LDC Lately...* to some of the theoretical issues regarding the learning of mathematics and the support offered by LDC instructors and programs. In addition to the well-known LDC Math Lab, we will highlight the various math support and learning resources that are offered by the LDC Math Program and the Office of Special Services.

Exploring Three Questions on the Learning of Math

WHY DO SOME STUDENTS EXPERIENCE DIFFICULTIES IN MATH LEARNING?

A variety of cognitive and non-cognitive factors impact college students' learning. They include: math knowledge, skills and understanding, disposition for learning math, educational experiences, learning styles, self perceptions, metacognitive skills, learning potential, problem solving skills, study skills, technology skills, belief systems, cultural backgrounds, and goals for learning math. According to the TIMSS (Third International Mathematics and Science Study) in the early 1990's, American math education covers more concepts in its curriculum than are covered in other countries, does it more superficially, and emphasizes math skills over in-depth understanding.

It is no wonder that there are students who are unprepared to handle college level math courses, even those with four years of high school math and a "B" average! These students' difficulties involve: memorizing math facts and formulas, not effectively using the math textbook, solving routine math problems and being tested more on skills versus understanding. They believe that math is not much more than a fragmented collection of rules and formulas. They often can perform the "mechanics" of math but have a severely limited understanding of the underlying math concepts and relationships. Even those who take an algebra or precalculus class similar to one they had in high school will comment on the "familiarity" of a problem but are unable to think their way through it easily. After years of taking math courses, they have failed to really see or experience the power and beauty of mathematics.

HOW CAN MATHEMATICAL MISCONCEPTIONS BE USED FOR TEACHING AND LEARNING?

It is easy to think that school imparts math knowledge into the brains of students. Numerous studies on the development of mathematical thinking, however, reveal that children, even before entering kindergarten, have already constructed intuitive notions, preconceptions or "naive theories" about mathematics out of their own everyday experiences. Early on, children of all cultures interact with mathematically rich, physical and social environments. Their mathematical ideas are often different from those of adults and experts, may take distinctive forms, and yet are similar to each other's at any given developmental level. What this means is that mathematical thinking is a natural and biologically wired activity.

Although children's "naive theories" may be incomplete or inaccurate, i.e. mathematical "misconceptions," these mathematical intuitions are, nonetheless, profound and deep-seated representations, both emotionally and intellectually, of how children use natural experiences to make mathematical sense of their world. They continue to become a basis upon which new mathematical ideas and understanding develop. Difficulties arise when students' informal understanding, so plausible in nature, is at odds with the formal mathematics instruction of their schooling. Traditional teaching generally has little influence on mathematical misconceptions. Students will simply misperceive or distort the classroom instruction to fit their existing preconceptions. Much of the time, neither the student nor the teacher is aware of these misconceptions. Students can learn to perform well in spite of them. They often survive by memorizing formulas, never recognizing connections to underlying mathematical principles.

The following problem, for example, confuses many students, including graduate engineering ones. Try it yourself. Write an equation using the variables S and P to represent the following statement. 'There are six times as many students as professors at a certain university'. Use 'S' for the number of students and 'P' for the number of professors. The most common error is to write "$6S = P$" instead of the correct "$6P = S$". There are several possible reasons for this error, some of which stem from preconceptions. One is the way that students think of the letters "S" and "P" as labels rather than as variables. Another is a misapplication of the "left to right" basis of reading English to constructing a mathematical equation. Unless asked to reflect on their equation, some students will not think to test its validity. Something has already clicked intuitively, and it is easy to assume its "rightness."

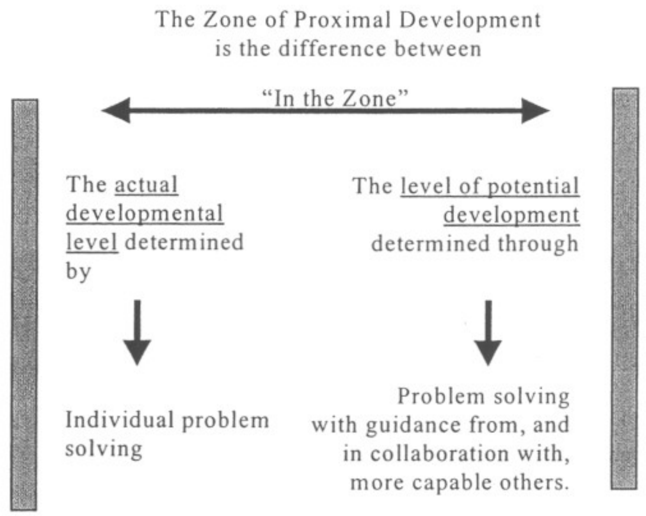
We, as educators, must learn how to identify and to challenge these deep-seated math misconceptions. They often lie well below the surface of a student's math performance, particularly if a student is simply doing "plug and chug" math or memorizing formulas and procedures. This superficial way of knowing can mask misunderstanding but still result in high grades! The research on mathematical thinking by Dr. Herbert Ginsburg indicates that most mathematical errors are not simply due to random mistakes. They usually represent intelligent efforts to construct meaningful math understanding with faulty or missing knowledge, illogical reasoning, overgeneralizing, misapplication of a rule, or misunderstanding. They are also more likely to be based on stable misconceptions shared by many students. Over many years, math instructors and even textbooks have developed lists of "classic errors" or misconceptions in arithmetic, algebra and trigonometry, as well as calculus.

Errors are opportunities to identify, assess, understand and respond to quantitative and qualitative dimensions of students' math skills and understanding. At the Learning Development Center we recognize the need to explore with students how they are thinking, what assumptions they are making, and what math skills and knowledge they are applying to any given math problem. If there are misconceptions, we will sometimes create math situations that gradually help students construct new understanding from old. At other times, it is necessary to dismantle the misconceptions through conflict and confusion to help the student begin to question and to refute his or her assumptions. This kind of math support is called "diagnostic teaching." It involves "cognitive clinical interviews" (Ginsburg, 1977), ongoing "formative assessments," and taking a bifocal perspective, "...perceiving the mathematics through the mind of the learner while perceiving the mind of the learner through mathematics" (Ball, 1993). We encourage students to identify, articulate and evaluate different points of view, to make conjectures, to reflect on the evidence that supports or refutes their claims, and, most of all, to realize that studying mathematics is more about applying and modifying their own understanding than simply learning what is provided by a text or an instructor.

WHAT IS THE ZONE OF PROXIMAL DEVELOPMENT?

This brings us to the primary role of the "zone of proximal development" (ZPD) and the LDC math instructors and student tutors. Two of the greatest influences on the understanding of cognitive development are L.S. Vygotsky and J. Piaget. Piaget said that children construct understanding through their actions on the world, whereas Vygotsky said that cognitive development is culturally mediated, a co-construction process between an active child and an active environment.

In Vygotsky's view, children are socialized into learning, acquiring cognitive skills from more capable others (teachers, peers, information technology) who assist and guide their development and performance, i.e. that a person's ways of thinking and doing are mediated by those of another. He defined the "zone of proximal development" as the "distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers." He also insisted that "what children can do with the assistance of others is even more indicative of their mental development than what they can do alone." What individuals can perform in collaboration with more capable others will lead them to perform at higher cognitive levels independently. The LDC math instructors and tutors provide instructional support that is based in part on students' current level of performance. In addition, they observe students' performance to assess their math strengths and needs, determine opportunities conducive to effective learning, enable them to accomplish what could not otherwise be done alone, and extend their potential for further development. Dialogue and social interaction are vital for meaningful communication and for developing higher level thinking tools.



(Vygotsky, 1978)

At the Learning Development Center there are collaborative study groups for CRP students where we assess and support students' math learning performance

> "I would argue that...interactions, and a sense of community–a culture of mathematics, if you will – are part of what sustains mathematics. And participation in that culture is how one comes to understand what mathematics is."
>
> –Schoenfeld, A.H., 1987

and learning potential. The "zone of proximal development" gives us an insightful way to observe more fully how students think, help them to articulate their understanding, and provide meaningful ways for them to succeed in their math studies beyond even their own expectations. Students have opportunities to contribute to the learning of others and to learn from others' contributions. We also understand the importance of maintaining supportive environments that are non-threatening and that encourage mutual respect and trust.

As part of diagnostic teaching, ZPD plays a central role. To assist a student who is struggling with homework problems, or to differentiate math learning potential from actual performance on a math test, responses such as, "That is an interesting mistake; let's try to understand it better" or "What math question would your answer be correct for?" or "What if you were to represent this problem in a different way?" are all ways to begin to identify a student's ZPD. If the answers are incomplete or inaccurate, we would continue to probe with new questions until a lower boundary of understanding is determined upon which to build new learning and independence.

One of our goals is to help students develop math abilities and new habits of mind that enable them to "think more like mathematicians." Several studies have already identified qualitative differences in "expert" and "novice" mathematical thinking and problem solving (Tall, 1999). At the LDC, we continue to strengthen our math/learning support and learning resources. We learn from our students, RIT colleagues and our own professional development to be aware of what mathematicians, math educators and psychologists continue to say about mathematics, its teaching and curricula, and the processes of math learning. It is valuable to note that RIT math students have a rich variety of ways to participate in "math learning communities" and to find math support on the RIT campus. Opportunities include:

- new freshman calculus workshops
- LDC Math Lab
- CRP math study groups
- Special Services Math Drop-Ins and individualized mentoring*
- "Tools for Math Success" workshops
- the expanded RIT Mathematics & Statistics Dept. study center in the College of Science
- individual or group sessions with their math instructor
- online networking with course materials.

*for students who qualify under Special Services guidelines

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Bringing Calculus Down to Earth

By K.C. Cole, Los Angeles Times Science Writer March 25, 1999

There's something about calculus. Mathematicians turn misty-eyed at its very mention. Students cringe. It's been praised as the highest intellectual edifice created by humankind, and dismissed as an absurdity that computes only "ghosts of departed quantities." Physicists will tell you it's the mathematical scaffolding behind our entire technological society; former students will tell you it's used for calculating the volumes of bananas. A philosopher might say it's the mathematics behind counting the number of angels that can fit on the head of a pin. In ever-more frantic efforts to bridge this gap, mathematicians are putting out dozens of new books and CDs designed to sell their favorite subject. These new approaches couldn't come at a better time.

These days, calculus is required for almost every even vaguely quantitative profession, from architecture to economics. Yet as many as a third of first-year undergraduates fail the course, according to mathematician Colin Adams of Williams College, one of the authors of the new book <u>How to Ace Calculus</u>. The book is dedicated to "all the students whose lifelong ambitions were dashed on the cliffs of calculus." Among those dropping over the edge, Adams says, are "a ton of students who have their sights set on, say, being a doctor. They take calculus, and then suddenly, boom, that's the end." The calculus crisis has set off what UCLA math chairman Tony Chan calls a "war" among mathematicians over how to teach this essential subject. Yet more than a decade of reform has not solved the problem.

"Your laws of motion were great, your development of calculus was incredible, but I really liked the cookies with the fig filling!"

A Constantly Shifting World

What is it about calculus that causes such fear and loathing in some, and ardor in others? What is calculus, anyway? In a nutshell, calculus is the mathematics of moving targets. Most mathematics deals with things that hold still: numbers and triangles and points and quantities. But the real world shifts constantly. Blood and electricity flow, temperatures rise, wind rushes, galaxies collide, empty space expands, continents drift. "Still life exists only in an art gallery," says mathematician Keith Devlin, dean of sciences at St. Mary's College of Moraga and creator of the CD and book <u>Electronic Companion to Calculus</u>, as well as other popular interpretations. Yet, until calculus was invented, mathematics couldn't get a grip on change. Pinning down motion might not seem to be that much of a problem. But the very idea presented countless paradoxes to the ancient Greeks. "Some things were Greek, even to Greeks," says David Berlinski in the opening of his charming and instructive book, The <u>Tour of the Calculus</u>. The Greeks couldn't make mathematical sense of how a chicken could cross the road, for example. Obviously, chickens do cross roads, but ancient Greek mathematicians reasoned that a chicken has to cross half the road, then half of the half that's left, then half of that half, and so on and so forth, ad infinitum. It will always have half of some interval left to traverse. To be sure, the steps the chicken takes in this scenario will get infinitely small. But there are also infinitely many steps to take. Ipso facto, you can't get there from here. You can't get anywhere.

The flaw in the Greeks' logic was the assumption that you can't add up an infinite number of things and get a finite answer. Calculus showed that you can. And once you can add infinite sums, you can do all sorts of amazing things–for example, calculate how an infinite number of angels can sit on the head of a pin. "That alone is one reason mathematicians find it incredible," Devlin says. "It's the human, finite mind finding ways to handle the infinite. To me that's just staggering." But the idea of adding up an infinite number of infinitely small pieces still boggles the mind. What does it mean, after all, to be infinitely small? What is the difference between infinitely small and nonexistent? "That was a really hard concept for people to deal with," Adams says. "Are these infinitesimally small subdivisions here or are they not here? Are they real or are they not?" These "infinitesimals" seemed so spooky to 18th-century British philosopher Bishop Berkeley that he dismissed them sarcastically as "ghosts of departed quantities."

Actually, calculus tames the infinite in two different, complementary ways. First, it can pin down instantaneous rates of change–for example, how fast is your car moving down the freeway? Further, it can pin down rates of change of rates of change–for example, how fast is your car accelerating or slowing down? By adding the total of an infinite number of infinitesimal changes, calculus also can compute the total amount of change. How much weight have you gained in your lifetime–despite all those ups and downs? Or, how much did you earn on that investment? Most important, calculus gives you a handle on how one thing changes as a function of something else. As master math expositor Martin Gardner puts it, calculus keeps track of how the number of toes in a family changes as a function of the number of persons the family contains. Gardner explains all this in the recently reissued best-selling 1910 book, Calculus Made Easy, by Silvanus Phillips Thompson, which Gardner still considers the best introductory calculus text on the market. The two faces of calculus grasp both the instantaneous flicker and the holistic sum.

Math Support at LDC

• DIAGNOSTIC TESTING

Appointments can be made for a thorough assessment of a student's level of competence in mathematics. The results will be discussed and a plan of action outlined when appropriate.

• INDIVIDUALIZED MATH

This is a non-credit course designed to provide a review of math topics for students who are not prepared to take a credit math course. Students are tested and a list of topics is identified for review. Working on their own from materials provided, students progress at a comfortable pace and complete each topic by passing a quiz at an 80% mastery level. Space is limited. Please contact Gail Gucker at 475-6944 or ghgldc@rit.edu for more information.

• MATH LAB - 2371 Eastman

Drop-in math help for all RIT students

Monday	10:00 am - 7:00 pm
Tuesday	10:00 am - 9:00 pm
Wednesday	10:00 am - 9:00 pm
Thursday	10:00 am - 4:00 pm
Friday	10:00 am - 2:00 pm

The tutors in the Math Lab can help students with questions from:

- homework ■ lecture notes ■ textbooks
- review sheets ■ practice quizzes and practice tests

• TOOLS FOR MATH SUCCESS SERIES

The "Tools For Math Success" workshops give students the opportunity to be at the controls of their math learning, to learn how to be an "intentional" math student. Below are some examples of workshops that are offered. Dates, times and topics vary so please check with Karen Quinn (475-2833 or kjqspr@rit.edu) for information about these workshops.

A Study Card System that Really Works
Are You a Global or Sequential Learner?
Classic Errors in Algebra
Overcoming Math Anxiety
Learning for Math Understanding
Do You Have a Funny Math Story?
Math Power Using the Infinity Walk
What is Calculus Really?
The Final Countdown
If I Knew Then What I Know Now

• CALCULUS REVIEW WORKSHOPS

The following Calculus Review Workshops are designed for students returning to their math sequence after a break in their academic program. Most often this includes returning adults and co-op students. These two workshops are offered during the second week of each quarter. Please check the of the quarterly schedule, *LDC Lately...* (student edition) for dates and times.

Calculus I Techniques Review
Differentiation techniques for students who have completed Calculus I (214, 241, 251 and 420)

Calculus II Techniques Review
Integration techniques for students who have completed Calculus II (242, 252, 421)

Problem-Based Learning

In his article,"Tutoring in Problem-Based Learning," David Kaufman (Faculty of Medicine, Dalhousie University) defines the problem-based approach (PBL) as " the learning which results from the process of working towards the understanding of, resolution of, a problem." He reports that many medical schools have begun to incorporate PBL into their curricula.

At Dalhousie University students meet with a faculty tutor three times weekly for two-hour tutorials which have incorporated a "case-oriented problem-stimulated" approach to discuss clinical cases. The goal of this approach is to enhance learning and develop skills at the higher levels of integration and application.

A similar approach is now used in RIT's revised 251 calculus sequence. The students spend four hours a week in traditional lecture classes and two additional hours in problem-solving sessions. In these sessions, students work in groups of three and are guided by faculty and teaching assistants as they explore challenging problems that are designed to lead to the understanding of calculus concepts.

PBL is an integral part of the math study groups organized and facilitated in the LDC for CRP students. The following article describes study groups in more detail. More information on PBL is available at the Web site mcms.dal.ca/gorgs/came/tutor.htm.

Math Study Groups

Several years ago, the LDC math instructors began the use of math study groups to aid students taking math courses while enrolled in the College Restoration Program (CRP). Approximately 40 students are enrolled each quarter in the CRP. Along with the courses within CRP on time management, academic strategies, etc., students generally take two credit courses. If two or more students are enrolled in the same math course (although possibly with different instructors), they are also assigned to a study group that is facilitated by a math instructor from the Learning Development Center (or occasionally a senior tutor from the Math Lab). The size of the group is limited to four or five members.

The study groups are held weekly for one hour throughout the quarter. At the beginning of the session, each student fills out a brief form reporting on homework effort in the past week and any quiz, project or test grades received. Each group member then lists particular problems or topics that he/she would like addressed during the session. These problems/topics are the focus for the session, with the facilitator identifying additional problems for consideration as deemed appropriate. Students then work together (in pairs or perhaps as a whole group) to discuss and solve the problems. The role of the facilitator is to pose questions during the process and to serve as a resource.

This approach to providing math support for students in the College Restoration Program has proven effective. For the typical student the small group setting provides an opportunity to process mathematical concepts in a setting that is friendly, focused and challenging. Student satisfaction, as evidenced by student evaluations at the end of the quarter, are generally quite high. Some students have mixed feelings at the beginning of the quarter regarding a required study group (approximately half report that their initial response was neutral to negative), but the evaluations at the end of the quarter are uniformly positive and frequently enthusiastic. Although these study groups are generally restricted to College Restoration Program students, participants occasionally continue in a study group voluntarily during the following quarter.

The LDC math instructors stress to group participants that the weekly study group does not replace the need to attend every class, meet with the professor during office hours, complete homework regularly, and to study on one's own. Students are also encouraged to make use of academic support settings on campus such as the LDC Math Lab and the College of Science Study Center. Study techniques are often discussed, and the instructors have observed that students sometimes plan among themselves for more group study periods beyond the scheduled one hour a week.

Should a Student Register for Calculus II?

In most cases, **NOT UNLESS** that student has earned a grade of C or better in Calculus I. An LDC study of 132 transcripts of students in the College Restoration Program (CRP) indicated that 81% of the CRP students who continue in a math sequence after earning a D in a prerequisite course are **NOT** successful in the sequence. Success is defined as earning a grade of C or better.

Early alert intervention and advisement can make a difference. Advising a student to retake Calculus I in order to master the material is more effective than allowing that student to continue in the sequence. The odds are that if the student continues with Calculus II, he/she may then end up having to retake both Calculus I and II.

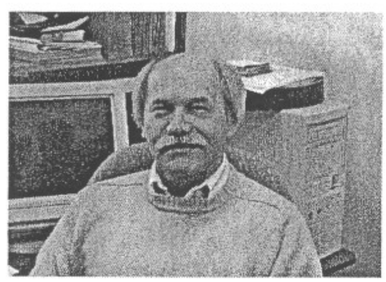
Profiles...

Karen Quinn has coordinated the RIT Office of Special Services Math Program since she was asked to create it in 1983. Although she has majored in mathematics at Carnegie Mellon University and University of Rochester, her real interest was more in the ways that some people struggled with it, losing confidence in themselves and their own math abilities, when rarely they were ever the real issue. At OSS, math support uses "diagnostic teaching" to help students understand their mathematical strengths and needs, develop more effective learning strategies, and experience both joy and success in their college math courses. Karen has also facilitated the RIT Student Affairs "Talking About Learning" Roundtable, participated in Project EDGE, is currently the advisor for the RIT Bowling Club, and serves on the Bennett Scholarship and other LDC committees. She loves spending time with her just-retired husband, reading, walking, gardening, baking, meditating, doing crossword puzzles, playing games and exploring on-line. Karen is the main contributor for this edition of *LDC Lately...*

Gail Gucker will celebrate 20 years at RIT this summer. Currently she is the Math Staff Chairperson at the LDC. In this capacity she is responsible for coordinating the math offerings from the College Program unit. She has created the Individualized Math Course for the College Restoration Program (CRP) and has worked one-on-one with many students who encounter difficulty with their math course work at RIT. She teaches in the summer HEOP Program, for the LDC, and for the Department of Mathematics & Statistics. Each quarter she organizes and facilitates a variety of study groups for CRP students in credit math courses. Gail's latest project has been the research on math profiles on entering students. A synopsis of this research appears in this issue and has been shared with department chairs and advisors. Outside of RIT she enjoys city living, Highland Park, the great out-of-doors, dancing, and jazz at the new Heritage House.

Ruth Jones has been a math instructor in the Learning Development Center for the past 15 years. Along with teaching in the LDC and developing instructional and evaluation materials, she teaches each year for the Department of Mathematics and Statistics. As supervisor of the Math Lab, she hires and trains the student tutors. Ruth has a strong interest in the use of small groups to facilitate learning and has worked in that area as Supplemental Instruction supervisor and a facilitator of math study groups. For several years she was a member of the Academic Senate and is currently a member of the Academic Affairs Committee. In her free time, Ruth is an avid reader and enjoys music and traveling.

Gail and Ruth use a team approach in collaborating on presentations on Problem Solving, How Students Learn Calculus, and The Use of Study Groups. In addition, they have worked together to train tutors and teaching assistants at RIT.



Wick Smith has been at RIT's Learning Development Center since 1969, first as a math instructor, then as the head of the LDC's Math Lab, and finally as the chairperson for College Program Services. Wick holds an MS in Statistics and Applied Mathematics from RIT and has taught part time for the College of Business, College of Science, College of Liberal Arts, and the College of Applied Science and Technology. At the LDC, in addition to his administrative duties, Wick works in the Math Lab, manages the LDC Web Site, and keeps all of the LDC computers running smoothly. Wick is a member of the Executive Boards of the New York College Learning Skills Association and the Genesee Figure Skating Club, and is a national-level official of figure skating in his "spare" time.