How Mathematics Education in Ohio Impacted the Nation: Laying the Groundwork for Reform*

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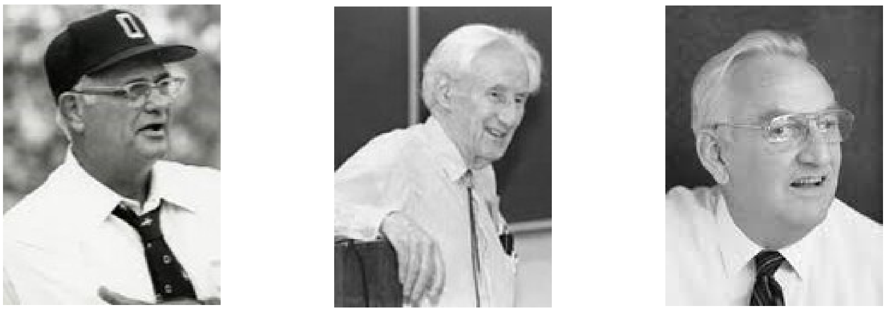
Abstract

This article describes significant contributions of OSU professors Arnold Ross, F. Joe Crosswhite, and others, who played key roles in providing access to appropriate mathematics for all students. Behind-the-scenes stories and personal anecdotes from the Ukraine to the OSU campus reveal how they laid the groundwork for improving the way mathematics is currently taught and the preparation of those who teach it, especially with regard to equity and technology. The article provides an insightful look into OSU's lasting impact on mathematics education.

Keywords: Mathematics education history, equity, technology, curriculum reform, Ohio State University

1 Introduction

Figure 1: Notable figures from Ohio State University.



Woody Hayes 1913-1987 | Arnold Ross 1906-2002 | F. Joe Crosswhite 1929-2020

When Ohio State—sorry, THE Ohio State University—is mentioned, many people immediately think of football. While there is good reason for this, it is also true that OSU has played a major role in influencing mathematics education throughout the nation and beyond. While other universities in Ohio have also made important contributions, behind-the-scenes stories will reveal how Arnold Ross' support for mathematics education in the department of mathematics and Joe Crosswhite's vision of a curriculum which provides mathematical power for all students in a technological society combined to set the stage for the following K-12 curriculum developments:

- Providing appropriate pathways for all students,
- Incorporating technology, especially graphing calculators,
- Including data analysis and probability as major components, and
- Developing courses to prepare teachers to teach the curriculum.

*Dedicated to the extraordinarily capable and caring colleagues with whom it has been such a joy to collaborate in addressing the vital work of mathematics education, and in appreciation to OJSM editor, Todd Edwards, for initiating this article and for his insightful guidance throughout the writing. –JES

No, Woody was not part of that—but he and Arnold had much in common. Woody Hayes and Arnold Ross were friends who shared values and looked out for each other's interests. Both recruited the best talent in the nation. Both fought tirelessly for all of the students who looked up to them. In 1970, both were on the OSU Oval trying to maintain peace during the student demonstrations. If they had been alive during the recent student demonstrations at Columbia University, OSU, or elsewhere, assuredly both of them would have strived to help to avoid escalating confrontations.

As I recall hearing at a memorial service for Woody in 1987, his team had one of the highest graduation rates in the nation, with Arnold ensuring that players got the tutoring and support they needed to pass math requirements. I also recall a time while working as Arnold's administrative assistant when he was frustrated because his calls to the governor of Ohio were going unanswered. Arnold "went over the governor's head" to the most powerful figure in Ohio, Woody Hayes. The governor called Arnold back within the hour! As subsequent examples will show, Arnold often thought "outside of the box" to solve problems!

This article will reveal how Arnold Ross, Joe Crosswhite, and their colleagues set the stage for these developments to become a reality. A common theme that will be found in the stories of these people is a deep concern for students.

2 Arnold Ross and the Department of Mathematics

Arnold Ross was known nationally for his summer programs for the nation's most elite math students, but he deserves additional attention here for his dedication to providing quality mathematical experiences for all students. He was a fierce fighter for his beliefs, especially with regard to racial equity. He used his position as chair of the OSU department of mathematics beginning in 1963 to team with Joe Crosswhite in the College of Education to build one of the most highly recognized mathematics education programs anywhere.

Arnold Ross as Others Viewed Him

An interview of Arnold (AMS, 2001—see link) provides an excellent overview of Arnold Ross (boldface mine):

> Arnold Ross has been a major figure in American mathematics for the past several decades. He is best known for his program for mathematically talented high school students which since its founding in 1957 has had various official names but is referred to, universally and fondly, as the Ross Program. Through this program Ross's love of mathematical exploration and his uncompromising standards have touched the lives of over 2,000 youngsters. From his years as a student at the University of Chicago in the 1920s and 1930s, through his positions as chair of the mathematics departments of Notre Dame University and of the Ohio State University, Ross came into contact with some of the leading mathematicians of the twentieth century. While he has always taken an active interest in research, especially in number theory, **his true calling is education**. He seemed always to be one step ahead, organizing a program to improve teachers' mathematical knowledge before Sputnik woke the nation up to the inadequacy of mathematics and science instruction, and launching a program for inner-city minority students before the term 'underrepresented groups' became a buzzword. In all his endeavors his aim is to kindle a passion for intellectual challenges.

In the interview, Arnold recounted his fascinating history. He was born in Chicago, in 1906, but at age three his mother took him to the Ukraine where she had family roots in search of a more secure life. Recognizing Arnold's unusual talents, an uncle arranged for private study with mathematician S. O. Shatunovsky, though able to pay him only with hard candy. When

WWI and the Russian revolution caused economic deprivation, Arnold returned to Chicago by himself at age 16, intent on studying at the prestigious Department of Mathematics at the University of Chicago. He worked long hours at a bookbinding business in order to earn enough money to enroll in a graduate level course with the famous topologist, E. H. Moore, who accepted him without a high school diploma upon the recommendation of Shatunovsky. In the only time I can recall Arnold talking about himself, he described the challenge he faced as a teenager in a class of graduate students. However, that changed when Moore cited the work of Shatunovsky, and Arnold was the only one in the class who understood it!

The interview revealed that the aim of the Ross program was not to turn all of the talented youngsters into mathematicians, but rather to give them, in Arnold's words, "a vivid apprenticeship to a life of exploration," with most of the students profoundly changed by the experience. Arnold pushed these talented "youngsters" (as Arnold referred to them) to "think deeply of simple things." Number theory provided the perfect vehicle for this, as deep questions could be posed with little prerequisite knowledge. Its success was attributed to his carefully-honed problem sets, counselors chosen from previous participants, and the "Ross effect."

More intriguing details of Arnold's life, including anecdotes about his inspiring teachers, his entanglements with the Russian authorities, and his narrowly escaping being a casualty of WWI, can be found in the August 2001 *Notices* (AMS, 2001—see link).

Another *Notices* article (AMS, 2003–see link) highlights his many outstanding qualities. In addition to what I have written below, Gloria Woods, Bert Waits, and eight mathematicians, three of whom were students in his summer program and three who started "Ross programs" of their own—including one in Germany—shared their impressions of Arnold. Bert Waits' description of what he called the "trailer incident" tells of one of the many times Arnold put the needs of his students ahead of his own.

Arnold Ross as I Knew Him

I was his administrative assistant for three years, following Bert Waits, who served in that position the three years before me. Arnold received his Ph.D. in number theory from the University of Chicago in 1931, but it was only when writing this article that I discovered that his mathematical heritage traced back to Leonhard Euler through noteworthy mathematicians, E. H. Moore, Leonard Dickson, Siméon Poisson, Pierre Laplace, and Joseph-Louis Lagrange. See genealogy.math.ndsu.nodak.edu (Mathematics Genealogy Project, n.d.) for more details.

I recall when I observed his classes, he would act "dumb like a fox," saying he couldn't read something or remember something, resulting in much of the course content being generated by the students, instead of being spewed out in lectures.

Showing his care for all students, he also led what he called "Sunday School," a program in which he and I and others tutored fifth- and sixth-graders from the inner city on campus (actually on Saturday mornings) and "New Careers," for adults from the inner city.

My most vivid memories of Arnold were of the student demonstrations about the treatment of Blacks and the opposition to the Vietnam War. Arnold was sympathetic to the students, but didn't like violence. His history of embracing math programs for Black students gave him a feeling of security during the unrest.

I witnessed this on May 4th, 1970, when Howard "Marks" Richard, another grad student, came into my office exclaiming that we had to go to the oval to convince Dr. Ross to leave his position between rioting students and bayoneted National Guardsmen, because Dr. Ross was "too old" to be there. Instead of leaving, Arnold convinced us to stay the rest of the day, joining neutral faculty members trying to keep matters from escalating. I didn't realize how serious the situation was until learning that evening how thirteen students had been shot by guardsmen at nearby Kent State University, resulting in four deaths.

Arnold, who was 63 at the time, proved not to be "too old." He went on to fight for students into his 90s. He once explained the hierarchy of the university this way: Students are most important, with faculty next, and administration least important.

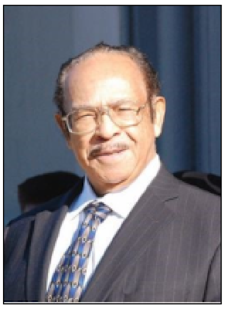
Arnold's previous extraordinary support for Marks is likely the reason that Marks was committed to supporting him. Marks had been accepted to come to OSU as a graduate student in the late 1960s. He and his family intended to live in a house trailer, but were turned away because Black families were not welcome in Columbus trailer parks. Arnold, not one to take "no" for an answer, then arranged for Marks and his family to have a trailer set up on the agriculture campus. Marks went on to earn his Ph. D. under Bud Trimble and become a mathematics professor at Norfolk State University, a predominantly Black college.

These remarks about Marks after his death show, in the spirit of Arnold Ross, Marks had "paid forward": "Dr. Howard Marks Simon Richard, Jr., led a life of resounding aspiration and accomplishment, committed to the education of all and uplifting our communities;" and, "He touched many lives during his time on this earth, as a community activist, a professor, a counselor to those in politics, and a good community leader" (Metro. Funeral Service, 2020).

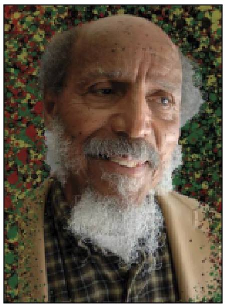
These things might not have been said if Arnold hadn't gone through extraordinary means to give Marks the opportunity to flourish at OSU.

I am familiar with two other notable contributors, though likely there are more. Richard Price, a professor of mathematics at Lamar University in Beaumont, Texas, who also earned a divinity degree from Yale, recruited and mentored Black students, and Wade Ellis Jr., formerly of West Valley College, who established a national reputation as second vice president of the MAA, Mathematical Sciences Education Board (MSEB) panel member, and author of numerous successful mathematics textbooks.

Figure 2: Notable students recruited by Arnold Ross.



Howard Marks Simon Richard, Jr.



Richard Price

Wade Ellis, Jr.

Arnold personified the equity principle of NCTM's *Principles and Standards for School Mathematics* (2000), which called for "high expectations and strong support for all students." I recall John Riedl, Dean of Mathematics and Physical Sciences, stating after Arnold's death that it would be difficult to name anyone at OSU who had done more for equity.

Though I never took a course from him, working with Arnold Ross was the high point of my educational experience at OSU. This remarkable man was one of the most influential people in my life and—I'm confident—in the lives of others. Arnold held a position with considerable power, which—in my view—he used to serve others. I wonder who, if anyone, wields such power at the university today—and what they are doing with it.

John Riner: Colorful, Caring, Complement to Arnold Ross

OSU Math Department Vice-Chairman John Riner (1924 - 1982) was the perfect complement to Arnold Ross. John, who had served in France before and after he received a Purple Heart as a U.S. Army Corporal, received his Ph. D. in mathematics at Notre Dame in 1947, while Ross was department chair. When Arnold came to OSU, he persuaded John to join him. I first met John while I was a high school teacher in Wisconsin, participating in an NSF grant that he directed. This led to a master's degree in mathematics and my administrative assistant status.

Ross was altruistic. Riner was pragmatic. He handled the immense challenge of overseeing the teaching of over ten thousand students per quarter by a staff of about a hundred professors and over two hundred part-time instructors and graduate students. As a result, I (and I'm sure Hank Waits) spent more time assisting him than assisting Arnold. Deeply concerned about the instruction of undergraduates by teaching assistants, many of whom barely spoke English, John did two things: (1) he initiated a program in which select faculty mentored small groups of teaching assistants, and (2) he and Joe Crosswhite recruited high school teachers to the OSU mathematics education Ph.D. program, where they taught three classes (instead of just one), supported by fee waivers and larger stipends. This innovation resulted in more undergraduate mathematics classes being taught by qualified teachers, at the same time creating a cadre of mathematics education students.

I recall a time when John implored Bert Waits to be the lecturer for a course with inexperienced foreign graduate students, so that "at least they would have a good lecturer." To help out and as a favor to John, Waits agreed on the condition that all of the sections would be taught by foreign graduate assistants, so that he wouldn't have to deal with students seeking section changes. (There's more to this story that won't be told here ...)

When people came to the main office asking to see Dr. Riner, a common directive was to "go down the hall to the office from where the cigar smoke was coming." John was inseparable from the small cigars he smoked. He was a very colorful figure on the campus, especially when driving his Lotus Elan sports car. But the main reason I speak of him here is that he modeled an attitude that I often recall to this day.

On my first morning as an administrative assistant, John gave me a task and asked me to report back later. When I told him what I had done, he said, "That's not what I expected you to do." Fearful that I had erred in my very first task, I was relieved when he said, "That's fine, your way is better." John left a lasting impression that when working together in a problem-solving situation, it didn't matter whose idea it was, so much as the quality of the idea.

Like Arnold, John was an advocate for the students. One day a graduate student came to me because he had been assessed a late fee, even though he turned in his registration materials to Dr. Ross on the first day. Arnold, who followed the progress of graduate students by reviewing their registration materials, was actually responsible for the cards reaching the registrar's office late. I called the registrar's office to explain, but was told there were no exceptions, that the student would have to pay the late fee. John, who was exasperated over frequent run-ins with the registrar, went over the registrar's head to the provost. When the registrar stood his ground, the provost scheduled a meeting with the grad student, the registrar, John, and me. It ended with the provost telling the registrar, one of the most powerful people in the administration, to "walk the student's registration cards through the lines himself without penalty!" I learned that day that even in one of the largest universities in the world there were people who cared about the students. John Riner and the provost—but perhaps not the registrar—were among them.

Once, when a faculty member was irate with me over his classroom assignment, John physically backed him up against the wall and told him that he should come to him rather than act out against a graduate assistant. Another time the same professor angrily returned an overhead projector to the office after one day in a new classroom proclaiming that "There's no way I can teach a class for a whole hour while writing upside down!" Apparently, he was so accustomed to turning his back on his students while writing on the chalkboard, that he didn't know that when using an overhead projector, he should face his students! Years later, Glenda Lappan, who I first met during my visiting appointment in the math department at Michigan State University, asked me to tell that story every time she saw me.

3 Joe Crosswhite and the Mathematics Education Department

F. "Joe" Crosswhite was, in my view, a "gentle giant." He came across as a humble man, a Missouri boy who had been teaching in a small Iowa town and came to OSU to later have a huge international impact on mathematics education. Perhaps what distinguishes Joe from others more than anything else is that he was not only one of the most informed people in the nation about the shortcomings of K-12 mathematics instruction in the 1980s, but that he led the way in an effort to improve the situation. He laid the groundwork to provide a vision of a broad math curriculum appropriate for all students in an increasingly technological society.

The NCTM formally recognized the scope of his experience when they awarded him the 1999 Lifetime Achievement Award, recognizing that he worked extensively on the influential Second International Mathematics Study (SIMS) in the 1980s, played a seminal role in the development of the Mathematical Sciences Education Board (MSEB), and chaired the Conference Board of the Mathematical Sciences (CBMS). Aware of the need, he left his position at OSU to devote full time efforts to the NCTM as its president from 1984 to 1986, when he created the NCTM Commission on Standards for School Mathematics.

As Peggy Kasten and I wrote in "What Every ~~Math~~ Teacher Should Know About Joe Crosswhite" (Kasten & Schultz, 2020), Joe spoke of none of this in his acceptance speech for the Achievement Award. Instead, he spoke almost entirely of Harold Fawcett.

> It was a personal letter from Fawcett revealing that he was familiar with Joe's personal details on his application that convinced Joe to come to OSU. A first course about the nature of proof with Fawcett convinced Joe to stay on to pursue a Ph. D. in mathematics education. Having lost his own father at age two, he considered Fawcett to be more like a father than any other man he had known, saying Fawcett was a kind, caring, generous, and loving human being.

In his NCTM President's Report "Better Teaching, Better Mathematics: Are They Enough?" (Crosswhite, 1986) Joe said this about Fawcett:

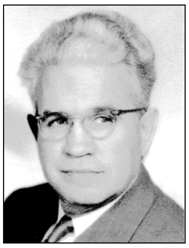


Fig. 3. Harold Fawcett.

> For me, Fawcett captured this philosophy best when he related an incident from his teaching experience. A mother attending a parents' night asked him, "How is Willie doing in mathematics?" Fawcett replied, "Madam, you ask the wrong question. You should ask, 'How is mathematics doing in Willie?'" Perhaps that is the only criterion we really need. Better mathematics may simply be the mathematics that does well in Willie.

More information about Harold Fawcett can be found in *Legacy of Leaders and History: Harold Fawcett* (Kullman, n.d.).

The K–12 Math Curriculum That Joe Assessed in the 1980s

The K-8 curriculum of the 1980s was largely driven by paper-and-pencil skills, a carry-over of "shopkeeper" arithmetic. The 9-12 curriculum was what I liked to call the mañana curriculum, consisting of prerequisite after prerequisite in preparation for advanced careers in STEM (Science, Technology, Engineering, and Mathematics) fields, even for the majority of students on other career paths. It was a curriculum that overemphasized manipulation of isolated skills at the expense of understanding how to combine and apply necessary skills to problem solving situations. It also largely ignored other important topics like analyzing and interpreting data.

This is how he described mathematics in 1986 in his President's Report:

> Let me begin with the prevailing view of what is better in mathematics. The patterns of emphasis in the goals and content of school mathematics have not been stable. On the contrary, their history has been more cyclical, exhibiting an almost periodic pattern of overreaction. What has been seen as an excessive emphasis in one direction in one generation has been replaced in the next by an equally unbalanced emphasis in an opposing direction. And that, ultimately, triggers a new reaction no less single-minded than the last. In the midst of a major revolution in school mathematics in the 1960s, some educators sensitive to this history cautioned that we not "throw out the baby with the bathwater." That warning would have been no less appropriate in the 1970s as we moved from the "new mathematics" to "back to the basics."
>
> I agree with the authors of the NACOME report (CBMS, 1975) that such polarizations of position have been counterproductive, that school mathematics suffers when it succumbs to false dichotomies when, as they put it, we allow ourselves to be manipulated into false choices between
>
> - the old and the new in mathematics;
> - skills and concepts;
> - the concrete and the abstract;
> - intuition and formalism;
> - structure and problem solving;
> - induction and deduction.
>
> These are indeed false choices. Every school mathematics program should seek reasonable balances between the elements of each pair. And yet, exactly these kinds of choices have characterized cycles in school mathematics.

SIMS was an attempt to advance mathematics education through international comparisons of intended curricula, implemented curricula, and student achievement. It was done under the auspices of the U.S. Department of Education and the National Institute of Education. Student performance was reported separately for content areas.

As a coauthor of the SIMS Summary Phase 2 Report (Crosswhite, 1985), Joe had early access to data comparing achievement and attitude data for eighth-grade and twelfth-grade students in the U.S. with 23 other countries, with the United States consistently ranking near the bottom. These excerpts from the report provide a glimpse of the report:

Overview

> The "typical" eighth grade mathematics program is dominated by arithmetic ...Within the eighth grade there was dramatic differentiation of mathematics courses offered, extending from algebra and enriched mathematics for the more

> able students to remedial arithmetic for the less able. And while the algebra classes covered much of the content of first year high school algebra, they omitted other topics, such as geometry, measurement and probability (p. 83).
>
> The twelfth-grade program was built upon a foundation that is by most international standards highly compartmentalized. In the U.S., high school mathematics typically consists of one year of algebra, one year of geometry, another year of algebra and then more advanced topics in the fourth year, such as analytic geometry, trigonometry, or calculus. In most countries of the world, a more integrated approach to mathematics is taken, in which the subject is presented in a more cohesive and unified fashion (p. 83).
>
> It is plausible that the "fragmentation" and "low intensity" found in many of our mathematics programs could be allayed by a more integrated approach to the high school mathematics curriculum (p. 83).

Calculator use[1]

> The extent of calculator use in eighth grade mathematics class was low (data collected in 1981-1982). Only 1 class in 20 used calculators for two or more periods per week. One class in three was not allowed to use calculators. Another one-third of classes reported never using calculator ...Calculators were used most commonly in eighth grade mathematics for checking answers to problems, for recreation or for doing projects. Little use was made of them in test-taking.
>
> Calculator use was much higher in senior high school mathematics than in junior high school mathematics classes. About one-third of the senior classes used calculators in class two or more times a week. Another twenty percent of the classes never used, or were not allowed to use, the calculator in class ...Calculators were most commonly used in senior high mathematics for checking work or solving problems. About one-half of the classes used calculators on tests (p. viii).

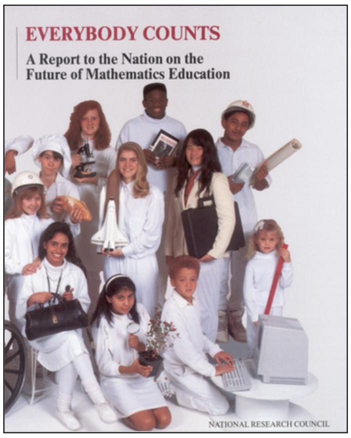
As mentioned above, Joe played a seminal role in the development of MSEB, who underscored the dire straits of the curriculum on page 1 of its 1989 report *Everybody Counts: A Report to the Nation on the Future of Mathematics Education in the United States* (MSEB, 1989):

> Yet, for lack of mathematical power, many of today's students are not prepared for tomorrow's jobs. In fact, many are not even prepared for today's jobs. Current mathematical achievement of U.S. students is nowhere near what is required to sustain our nation's leadership in a global technological society. As technology has "mathematicized" the workplace and as mathematics has permeated society, a complacent America has tolerated underachievement as the norm for mathematics education. We have inherited a mathematics curriculum conforming to the past, blind to the future, and bound by a tradition of minimum expectations.

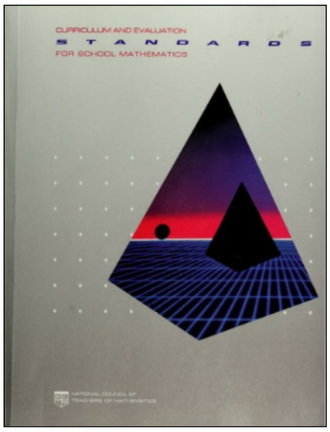
Though it came out the same year as the *NCTM Standards*, the author teams occasionally met together and exchanged information, so that MSEB recommendations were incorporated into the NCTM *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989a). As mentioned above, Wade Ellis, Jr., was a member of the MSEB panel, as were Steve Meiring and Zalman Usiskin, both with whom I often collaborated.

[1]refers to 4-function and scientific calculators – graphing calculators did not exist

Figure 4: Mathematics Reform Documents: (a) ’Everybody Counts’ and (b) the 1989 NCTM Standards.



(a)



(b)

Observing that about half the students left the mathematical pipeline from ninth-grade mathematics to advanced degrees in mathematics over the years from 1972 to 1986, the report famously said (p. 6) “mathematics should be a pump instead of a filter.” (I recall hearing while teaching calculus for prospective School of Business majors at OSU in the early 1970s that the business school looked to the math department to make the course more difficult to weed out the large number of students seeking entry. If true, a clear example of using mathematics as a filter.)

The Outcome: The 1989 NCTM Standards

Drawing on the SIMS data with input from MSEB, Joe created the NCTM Commission on Standards for School Mathematics. The main ideas of the *Standards* are summarized on page 255 of the recommendations (NCTM, 1989a):

> The document creates a vision of
> - mathematical power for all students;
> - mathematics as something one does—solve problems, communicate, reason;
> - a curriculum for all that includes a broad range of content, a variety of contexts, and deliberate connections;
> - the learning of mathematics as an active constructive process;
> - instruction based on real problems;
> - evaluation as a means of improving instruction, learning, and programs.

Each writing team included a classroom teacher and specialists dedicated to research and to equity. With Joe’s influence, it is likely not a coincidence that four recent OSU Ph. D. graduates were among the 24 authors of the writing groups: Hal Schoen and Bert Waits (9-12), Jim Schultz (5-8), and Chuck Thompson (K-4).

A significant feature involved the timing. The writing teams met three different times for two weeks over two years, with a widely circulated draft made available between the first and second years in order to facilitate obtaining as broad a range of input as possible. The final version was endorsed by the American Mathematical Society (AMS), the American Statistical Association (ASA), the Association of Women in Mathematics (AWM), the Mathematical Association of America (MAA), the Mathematical Sciences Board (MSEB), the National Council of Supervisors of Mathematics (NCSM), the School Science and Mathematical Association (SSMA), and many other organizations and professional groups.

In looking back over the *Standards*, Joe recalled, "We bucked the trend at the time. People couldn't separate the notion of national leadership from the specter of national control. But we showed that it was possible" (NCTM, 1989b). Joe's work certainly exemplified PSSM's Assessment Principle, that assessment should support the learning of important mathematics and furnish useful information to both teachers and students, at the international level.

Mathematics Education Faculty

Each member of the outstanding mathematics education faculty is deserving of attention here. Peggy Kasten, a Ph. D. student of Joe Crosswhite, who joined the faculty after working for the State Department of Education for almost twenty years, said this about the faculty:

> The mathematics education faculty at Ohio in the late 1970s and early 1980s was truly a dream team, and while unfortunately the names are not as familiar as they should be today, at the time it was dazzling: Harold Trimble, Richard Shumway, Jon Higgins, Alan Osborne, Marilyn Suydam and Joe Crosswhite. And this doesn't even include the great mathematics educators in the Ohio State Mathematics Department, Frank Demana, Joan Leitzel, Jim Schultz, and Bert Waits (M. Kasten, personal communication, August 23, 2020).

Out of consideration for length, only Marilyn Suydam and Bud Trimble will be featured here: Marilyn because of her noteworthy dissemination of research in calculator use, and Bud Trimble because he was the advisor to both Bert Waits and me.

Marilyn Suydam, International Leader in Calculator Research Dissemination

While John Riner and Bert Waits were innovating the use of prototype calculators in the OSU math department, Marilyn Suydam used her mathematics education position to create and direct the Calculator Information Center at OSU. Under Marilyn's direction, the Center compiled, translated, and summarized international research on the use of calculators in the 1970s and 1980s.

Fig. 5. Marilyn Suydam (1932-2022).

"Calculators Gain Favor," an article which appeared in the OSU student newspaper, *The Lantern*, on May 5, 1976, reported that Suydam herself felt that "calculators are a good thing," and that they could be used in elementary schools as low as the first-grade level (Suydam, 1976). The main reasons cited by persons in favor of calculator use in elementary schools is the "fact that they do exist." Other reasons given were that they aid in computation, they lessen the need for memorization, they help in problem-solving, they motivate, and they aid in exploring and understanding math. The reason most often given against the use of calculators is that "children will use the calculators instead of thinking it out for themselves."

Marilyn published an abundance of research summaries, many of which appeared in the *Journal for Research in Mathematics Education*. Here is an example of her work.

> This document summarizes the research done on calculators and calculator use. It is noted that calculators are now seen as acceptable, with fears about use in school currently infrequent, and the role of such devices much more evident than 6 years ago ...It is noted that within the 75 studies used in this analysis, 35% provide evidence that students score higher when calculators are used, 44% indicate no significant difference, 19% report mixed findings, and only 3% report calculator use led to lower student scores (Suydam, 1982).

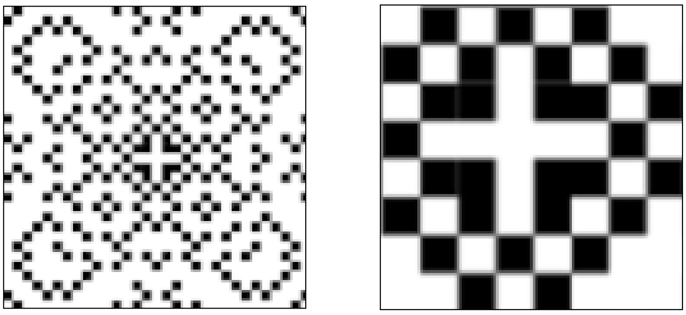
Marilyn also received numerous grants in support of her work. She was awarded the NCTM 1988 Lifetime Achievement Award "for making research findings accessible to teachers and others in mathematics education." This and other work by Marilyn Suydam, as well as Bert Waits and others, can be retrieved from https://eric.ed.gov/, a very useful website.

Artificial Intelligence today is the analog of the 4-function calculators in the 1970s. This raises an interesting question: who is performing this important task of disseminating research about AI today, and what are they saying about its use?

Harold "Bud" Trimble, Mathematics on Display

While improving education was a focus in the OSU department of mathematics, respect for sound mathematics was evident in the mathematics education department. When I first walked into the office of my Ph. D. advisor, Bud Trimble, I noticed a wall hanging in his office, like the one shown in Figure 6a.

Figure 6: A plot of Gaussian primes in the complex plane (Weisstein, n.d.).



(a) (b)

When I asked him what it represented, he told me it was a graph of primes in the complex plane, where each number has a real coordinate and an imaginary coordinate. Primes in the complex plane, called **Gaussian primes**, are the counterparts of ordinary primes. For example, in the second figure, with the center square as the origin $(0, 0)$, $3+2i$ is represented by a black square in the $(3, 2)$ position, indicating that it is a Gaussian prime. However, the square in the $(3, 1)$ position is a light square, because it is not a Gaussian prime, since $3+i = (1–i)(1 + 2i)$.

The figure displays both patterns and symmetry, two key mathematical concepts. It conveys **mathematics** without a single word or number. This illustrates that mathematics is much more than computation! Patterns, symmetry, and relationships are all important parts of mathematics!

It's fascinating that while $7 = 7 + 0i$ is also a Gaussian prime, $5 = 5 + 0i$ is not, since $5 + 0i = (2+i)(2-i)$. Moreover, all primes of the form $4k+3$ are also Gaussian primes, while no primes of the form $4k + 1$ are Gaussian primes. This means, that if you ask is "Is 5 a prime number?", the answer might be "It depends. 'Yes' in the integers, 'no' in the complex numbers, since then $5 = (2 + i)(2 - i)$." (Of course, by default we are referring to the integers, where we say 5 is prime.)

This is akin to understanding how our system of numbers grows as our knowledge of mathematics expands. While $x - 1 = 0$ has a solution in the whole numbers, the equations $2x = 1$, $x + 1 = 0$, $x^2 = 2$, and $x^2 = -1$ do not. However, each of the equations does have a solution if we know about fractions, integers, irrational numbers, and complex numbers respectively.

Not only did Bud's office decor reveal his deep appreciation for the beauty of mathematics, but it turned out later to be related to a 6th grade class. Students were investigating which kinds of triangles can be constructed on a geoboard (a geometry exploration tool—a homemade version consisting of 25 smooth nails pounded into a square piece of plywood in a 5×5 array, with figures formed by rubber bands stretched around the nails). When students investigated whether it was possible to construct an equilateral triangle with vertices at the lattice points (nails), I knew that the proof that it was impossible involved numbers of the form $4k + 3$. This is also the key to which complex numbers are Gaussian primes, a question I could answer only because I studied higher level algebra. A proof of the impossibility appears in (Schultz and Burger, 1984). (Incidentally, William Burger was also an OSU Ph. D. mathematics education graduate, a student of Richard Shumway.)

Bud was the consummate advisor. He was helpful, with a great sense of humor. In the acknowledgments of my Ph. D. dissertation, I wrote, "He makes you feel better about your mistakes than others made you feel about your accomplishments." A Scott Foresman author, he not only taught me better writing techniques, but was instrumental (along with Zalman Usiskin) in finding a place for me as a Scott Foresman author when he left the writing team.

4 Conclusion

I have attempted in this article to view Arnold Ross and Joe Crosswhite in light of their concern for others and for their devotion to the teaching of mathematics. It was the environment that they and their colleagues provided that gave an opportunity for mathematics educators in the department of mathematics, Bert Waits and me, to join Frank Demana, Joan Leitzel, and other mathematicians to focus on the four developments mentioned at the beginning of this article. I am proud that Arnold and Joe are a key part of my mathematics education heritage. The strong ties between mathematics and mathematics education that existed then are suitably illustrated in this photo taken at my Ph.D. graduation party in 1971, with Arnold and Joe side-by-side, and Joe and Bert joining hands.

Figure 7: Bud Trimble, Arnold Ross, Joe Crosswhite, Bert Waits, and Jim Schultz.

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