What Does C++20 Owe to Prof. Dr. Emmy Noether?

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A little about me

- B.A. (math's); M.S., Ph.D. (computer science).
- Professional programmer for over 50 years, programming in C++ since 1982.
- Experienced in industry, academia, consulting, and research:
  - Founded a Computer Science Dept.; served as Professor and Dept. Head; taught and mentored at all levels.
  - Managed and mentored the programming staff for a reseller.
  - Lectured internationally as a software consultant and commercial trainer.
  - Retired from the Scientific Computing Division at Fermilab, specializing in C++ programming and in-house consulting.
- Not dead — still doing training & consulting. (Email me!)

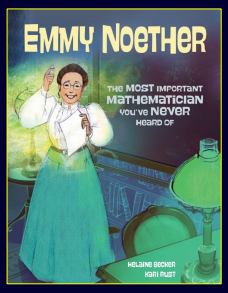
 2

Emeritus participant in C++ standardization

- Written ~175 papers for WG21, proposing such now-standard C++ library features as gcd/lcm, cbegin/cend, common_type, and void_t, as well as all of headers <random> and <ratio>.
- Influenced such core language features as *alias templates*, *contextual conversions*, and *variable templates*; recently worked on *requires-expressions*, operator<=>, and more!
- Conceived and served as Project Editor for *Int'l Standard on Mathematical Special Functions in C++* (ISO/IEC 29124), now incorporated into C++17's <cmath>.
- Be forewarned: Based on my training and experience, I hold some rather strong opinions about computer software and programming methodology — these opinions are not shared by all programmers, but they should be! ☺

 3

"The Most Important Mathematician You've Never Heard Of"



"Scientists are a famously anonymous lot, but few can match [the] perverse and unmerited obscurity [of] the 20th-century mathematical genius Amalie [Emmy] Noether."

— Natalie Angier, *The New York Times*, 2012-03-26

 4

Emmy Noether (1882-1935) [adapted from A. Borschel-Dan]

- Although she was a mathematician's daughter, she was not allowed to enroll in Univ. classes:
  - The academic senate warned that coed education would "overthrow all academic order." *E.g.*, a faculty member said, "What will our soldiers think when they … find that they are required to learn at the feet of a woman?"
  - To which mathematician David Hilbert famously replied, "I do not see that the candidate's gender is an argument against her admission…. After all, we are a university, not a bathhouse."

- Noether was at last officially permitted to study, but had to ask permission from each lecturer she attended.

 5

At the start of her career

- After winning the right to matriculate, Noether earned a Ph.D. in 1907, but no faculty jobs were then open to women:
  - So she worked without pay for 7+ years.
  - Then "hired" by Hilbert at the Univ. of Göttingen in 1915, but spent years lecturing under his name, still unpaid.
  - Finally appointed *Lehrbeauftragte für Algebra* in 1923, she fled to the U.S.A. in 1933 to escape Nazi persecution.
- She "produced papers and theories at a staggering pace," including many rarely acknowledged contributions to works written by her students and colleagues.

 6

In the USA, she joined Bryn Mawr, with ties to Princeton's IAS

- "Dr. Noether is the most eminent woman in mathematics in Europe and has had more students at Göttingen than anyone else in the department."

  — Dr. Marion Edwards Park
  President, Bryn Mawr College

- "Miss Noether's methods of thinking and working … were [to] recognize the unessentials [and] brush them aside…. This was … far from a superficial achievement…."

  — Dr. Ruth Stauffer,
  Noether's last doctoral student

 7

Some of Noether's significant contributions

- "The development of abstract algebra, … one of the most distinctive innovations of 20th century math's, is largely due to her – in her published papers, in lectures, and in … influence on her contemporaries."

  — Nathan Jacobson

- *Noether's Theorem* [1915, pub. 1918] is "one of the most important mathematical theorems ever proved in guiding the development of modern physics, possibly on a par with the Pythagorean theorem."

  — Leon Lederman & Christopher Hill

 8

"Emmy Noether saved General Relativity" w/ her theorem

- "[Since] 1915, General Relativity, a new … way of thinking about gravity, had captured the attention of physicists…. But [this new theory had] difficulties which even Einstein could not resolve.
- "We would likely not be celebrating this landmark theory were it not for [Emmy Noether] who, at her prime, couldn't even secure a teaching role in her homeland because of her gender.
- "[Noether's Theorem provided] the mathematical breakthroughs that general relativity needed to win over physicists."

  — Robert Lea

 9

But Noether is now recalled by relatively few of us

- Her mathematical originality was "absolute beyond comparison"

  — Bartel L. van der Waerden

- She "changed the face of algebra by her work."

  — Hermann Weyl

- She "is … the greatest woman mathematician who has ever lived; and the greatest woman scientist of any sort now living, and a scholar at least on the plane of Madame Curie."

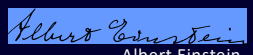
  — Norbert Wiener

 10

A very special posthumous tribute [excerpted]

- **"Within the past few days a distinguished mathematician, Professor Emmy Noether, … died in her fifty-third year.**
- **"In the judgment of the most competent living mathematicians, [she] was the most significant creative mathematical genius thus far produced … ."**

Bryn Mawr College Grounds



— Albert Einstein,
"Professor Einstein Writes in Appreciation of a Fellow-Mathematician,"
The New York Times, 1935-05-05

 11

A biographer summarizes

- "In her 53 years,
  - "many spent bucking a system that impeded her pursuit of mathematics,
  - "Noether had an extraordinary impact on both algebra and physics.
- "There's no telling what else she might have accomplished if society and fate had been more kind."

  — Steve Nadis,
  The Universe According to Emmy Noether

 12

What does Noether's work have to do with C++20?

- "It was she who taught us to think in terms of simple and general algebraic concepts…."

— Pavel S. Alexandrov

- "For Emmy Noether, relationships among numbers, functions, and operations became … amenable to generalisation … only after they have been … reduced to general conceptual relationships…."

— Bartel L. van der Waerden

 13

"The greatest thing … in 20th century mathematics!"

- "What was [Noether's] idea? [It was that y]ou could separate concepts from implementation. You could just deal with concepts….
- "So, if anybody invented generic programming, she did…. She realized it all. She realized that you could fully separate these two things.
- "Her contribution needs to be remembered."

— Alexander Stepanov, 2003

 14

Emmy Noether, "Mathematical genius"

"Even now, the world still learns from Noether, whose abstract principles are fundamental…."

— *Emily Barone, 2020*

 15

C++20 Owes Concepts to

Prof. Dr. **Emmy Noether** ע"ה

"Her contribution needs to be remembered."

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