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Mathematics Education through the Lens of Gerald Goldin

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I had the honor to speak with Doctor Gerald A. Goldin as he shared his personal and professional experiences in mathematics education. He is currently a distinguished professor at Rutgers University. As a faculty member, he is professionally affiliated as a member of the graduate faculties in mathematics, physics, and education. He is an associate of the Center for Mathematics, Science, and Computer Education as well as a permanent member of the Center for Discrete Mathematics and Theoretical Computer Science (DIMACS).

Goldin was born in 1943 in Brooklyn, New York where he spent his early childhood. Both his parents are former educators; his father was a high school mathematics teacher. His family then moved to Long Island, New York in 1949 where he received a first grade to twelfth grade level education. During his teenage years, he was involved with the chess team and math league in school which often won competitions. Afterwards, Goldin found himself applying to a number of colleges for his undergraduate education. He decided to attend Harvard University in 1960 where he studied Chemistry and Physics. He graduated magna cum laude and received his Bachelor of Arts degree in Chemistry and Physics in 1964. At Harvard he also studied philosophy. Directly afterwards, he continued his education at Princeton University from 1964 to 1968. There, he received a Ph.D. in Physics in 1969, specializing in Theoretical and Mathematical Physics.

In 1968, Goldin moved to Philadelphia where he lived with his family for nine years. This was also the beginning of his exploration into an education career. He taught part time at the high school level in Philadelphia and gained experience through field observations in a number of pre-K - 12 schools. Through this, he witnessed inequalities of the education system which greatly influenced him. For example, he observed two classrooms which differed greatly in the resources available as well in the expectations of students. Both environments varied greatly in that one supported the development of students while the other did not. Goldin defined it as “a social segregation within a big city system that takes certain kids and puts them in an environment where they are going to flourish and other kids an environment where they are not.” He questioned why this was so. Goldin concluded that politics and economics has affected this inequality gap. Another take away from his field observations was that students are rather smart, much more than we think they are. He saw many instances of students asking very profound questions that reflect a lot of insight. Often, the teacher could not understand that it was a very good question. Because the teacher was focused on teaching in one way and the question was not in that direction, the student’s idea was often dismissed. As teachers were unable to answer their

questions, it becomes a missed opportunity. Through many of these instances, Goldin came to see a lot of great potential in students as well as many missed opportunities occurring in the mathematics classroom.

Throughout his career, Goldin wrote a number of papers advocating taking a scientific perspective in studying the learning of mathematics. He came to notice that many educators do not advocate for this or are explicitly against it. Goldin has found that many of his colleagues felt the scientific approach was very rigid, authoritarian and inappropriate for education. They argued that every child is different so one cannot reach any generalizations. Goldin questions, "If you are unable to have something more general than that, how are you going to have policies that promote effective teaching?" In 2003, Goldin published his article "Developing complex understandings: On the relation of mathematics education research to mathematics." In this, he addressed the cultural divide between the field of mathematics and mathematics education research. In collaboration with his doctoral student Valerie DeBellis, Goldin wrote an article for the journal Education Studies of Mathematics in 2006 and spoke about the role of the affective domain in learning mathematics. He has worked in collaboration with Yakov Epstein, a professor of psychology at Rutgers, Roberta Schorr, a professor in urban education at Rutgers with a specialization in mathematics, and Lisa Warner who is a professor of mathematics education at William Paterson University. Together, they published an article, "Beliefs and engagement structures: Behind the affective dimension of mathematical learning." It covers the impact of affect, beliefs and motivation on student learning from a psychological perspective.

Goldin often travels for conferences or collaborations with individuals from other institutions. While some of his travels are for scientific conferences in mathematics and physics, he still branches out in search of connections with mathematics education. Through doing so in the 1980s, 1990s, and subsequently, he has learned from the differences in the education approach of Germany, France, etc. as they are very different and vary from that of America. Recently, he has been to Benin, Africa to work with another mathematician to contribute to science in Africa. It is very important to the development of Africa to be able to build up the structure of education of science and math on all levels. Goldin has been teaching there at the Ph.D. level of mathematics and while doing so, has learned what the gaps are and what the students are receiving in their preparation. As well, he looks as what needs to be done to fill that. Goldin is currently seeking to develop a partnership with Rutgers University and institutions in Africa to contribute to development of professional education in Benin. The government in Benin is currently trying to build a new project and if starts up, it may be in development for many years. Meanwhile, his personal connection has lasted a duration of about 15 years. He has made multiple visits, short and long with longer visits lasting for a month.

Naturally, his travels allowed him to compare and contrast the European and American education system. A key take away was that most Europeans value education much higher than Americans do. Teaching is a prestigious position in many European countries versus the bashing of teachers by many politicians in America. Consequently, teacher salary is higher in some of Europe, and career professional status is higher. Goldin notes that a large factor behind this is in not just how schools are managed differently but how societal culture varies. Many European

countries are rigid, in which teachers lack autonomy in the curriculum. For example, Germany has a national curriculum and all the schools are teaching by this. It is a good strong curriculum in mathematics. Student's qualifications are more tracked through a variety of high school options and a standard entrance exam for all colleges. While in America, we can apply to different colleges, which make use of multiple different standards separately.

When he visited Germany in late '80s, early '90s, he visited some sites for early computer education as it was just getting off the ground. They were in the process of deciding in a centralized way of what models should be purchased by schools, what the curriculum was going to be, etc. In terms of technology, their national curriculum was a constraint on the ability for further discovery. Meanwhile in America, all schools varied in their standards for technology which allowed for more exploration. American teachers were less guided as they had not been trained in teaching with technology in mathematics classrooms. However, there were more occurrences of teachers discovering a new method of teaching and students discovering a new concept. Sometimes the students would be teaching the teachers how to use the software; it was completely anarchic. All the while, Germany struggled in new inventions. In this sense, the American education system was much better. Many well-known companies have been initiated in America: Apple, Microsoft, Facebook, etc. due to the absence of a national curriculum in the technology area. Hence people were able to simply explore, discover, and learn; it was much less uniform. In a rigid system, when you have a rapidly changing field like computer science, a rigid system cannot keep up with it.

Math is rapidly changing in many ways but the school math is not. The curriculum is not open to new content today. For example, fractal geometry was a whole new field of mathematics which did not exist when Goldin went to graduate school. Now, schools should be incorporating this as it is very applicable and very interesting. Although one does not require advanced prerequisites to study or explore new math concepts, it is not happening in the classrooms. That is due to the rigidified and centralized testing which does not allow it to be incorporated. Unfortunately, there are other areas of mathematics that are just as important and easily accessible to students, but they are not in the standards so they are not being taught. One example of such an area of math is the wide-ranging field of discrete mathematics.

The emergence of the testing industry has affected mathematics education in Goldin's education experience. The industry is now largely developed. In his lifetime, it began with the SAT. It began as one test at one point and then each state developed one by a certain group for specific courses. For example, New York implemented Regents testing where there is one in algebra, geometry, etc. However, students were not required to take the Regents course. Overall, regulations were all done state by state. Now we have a massive testing industry with standardized testing. Standardized testing is doing a lot to change teaching but not in a positive direction.

Throughout his experience, Goldin has seen the pendulum swing from one way to the other. He explains this occurrence as due to the fads in education. In 1940s and 1950s, most of his precollege education, math was taught in a very traditional way based on computational skills, not conceptual understanding. Fortunately for some kids, they understood the concepts

anyways. However consequently, the rest simply just learned the procedures. The first course they would take that had concepts in it was geometry. Euclidian geometry required students to understand logic and proofs. Before that, logic was rarely talked about in the classroom. In the ‘60s, there was the New Mathematics Movement in which leading mathematicians advocated for more advanced mathematics to be brought into the schools. But by and large, this was not very successful. During this time, America was occupied with the Cold War. Sputnik had been launched by Russia so Americans feared Russia was getting ahead and there was a big push in math and science and technology. A lot of money went into this push. However, they did not have the massive preparation of teachers which was needed to teach a lot of the new mathematics. Thus, the successes were not consistent, as some goals were accomplished while some were not.

Following, the pendulum swung the other direction and there was a big movement called Back to Basics. This movement suggested to throw out all the new mathematic concepts and teach the basic skills. This was very popular in the ‘70s and went onto the early ‘80s. In the ‘80s, it swung again the other way in reform mathematics. There was more emphasis on discovery and learning in the classroom. In the ‘80s and ‘90s, problem solving became more significant. Hence, there was a general trend that started moving back towards this perspective. Now, the latest swing pointed in the direction of accountability and standardized testing called Standards Movement. This is where we are now and of course it will swing again. It is just part of the social dynamic of a large country that is subject to political forces that are not especially knowledgeable about education.

The biggest political change which Goldin has experienced was the impact of the Civil Rights Movement. At the time, Goldin was growing up in New York and the southern states were racially segregated in education by law. In the northern states, racial groups were not separated by law but often by demographics. This was termed de facto segregation in which certain communities were largely populated by a specific ethnicity. Hence, the schools were still community-based and in fact segregated, although no law prevented an individual from attending a school based on race. Consequently, housing segregation led to school segregation. Then, the Civil Rights Act of 1968 banned housing discrimination. So, people buying and selling houses were no longer able to legally deny access to people based on race. The change in making segregation illegal has, although effects are very slow, made a big effect. While inequities are still prevalent now, they were more prominent in the past than now.

Another major political change has been in equal rights for women, and the encouragement of women and minorities to enter STEM fields.

There is always inconsistency and debate regarding the content of the curriculum. The content has been changing with each pendulum swing. Politics have tended to govern such changes rather than the understanding and expertise of people teaching who know the field. From here is where individuals who specialize in science and mathematics are divided from those who are leaders in education. This divide has contributed to the way in which politics has irrationally swung without genuine, thoughtful development.

For the mathematics education field, Goldin feels it would thrive best with much more flexible standards. As students should not be viewed as products, standardizing math education is detrimental. Instead, varied opportunities for students should be created with a curriculum that allows for flexibility. A curriculum should allow for different choices and different paths which students can take according to how rapidly they learn, ability, their ambition and motivations. Overall, the teaching profession should be elevated. Teachers should be expected to be experts in the mathematics they are teaching and in many different ways of teaching it. With more autonomy, educators will be able to tailor their instructions to the needs of the students they are teaching. Goldin feels that students should have more flexibility in the paths that they follow rather than following one rigid set of standards which applies to every student. That means a variety of curriculum possibilities with an inclusion of advances in math.

The mathematics currently being taught in schools has all been discovered before the year 1800, with a few exceptions. There has been a number of new advances in mathematics and many of these do not require advanced prerequisites. There is a misconception that one cannot understand new discoveries if one does not already have a graduate degree in math. However, many new discoveries in mathematics can be adapted to be accessible for young students.

Much of the current curriculum was at one time very advanced and abstract. For example, fractions were only accessible to a very limited population of individuals when they were first invented and developed. Negative numbers were a revolutionary idea in math that mathematicians debated. Algebra was likewise an advanced subject for advanced mathematicians that we now teach to kids. Unfortunately, we stopped the process of bringing advanced ideas into the curriculum although these ideas spark interest in young students. By doing so, mathematics becomes a living subject. Living not in a sense that you can apply math to everyday needs but living in the sense of discovering new ideas and finding patterns. Goldin would like to see more recent discoveries being incorporated into the curriculum. It is crucial to note that these mathematics concepts should not to be taught as procedures but through discovering patterns, finding relationships, and building conceptual understanding. Hopefully over time, we will be able to witness these aspects in the mathematics education field.