

Helena Rasiowa (1917-1994)

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Abstract. This is a biogram of Professor Helena Rasiowa (1917-1994) one of the leading representatives of logicians from Warsaw. She was not only the great scientist but also the great human being. Rasiowa influenced numerous researchers from all over the world, especially by her results in algebraic logic, as well as by her great contribution for the mathematical community in all respect. She is also co-founder of the Pawlak-Rasiowa School of Artificial Intelligence (AI) [4].

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The only way to rectify our reasoning is to make them as tangible as those of the Mathematicians, so that we can find our error at a glance, and when there are disputes among persons, we can simply say: Let us calculate, without further ado, to see who is right.

G. W. Leibniz [5]

Helena Rasiowa was born on June 23, 1917. During her school days and also later, she attended piano classes at the Fryderyk Chopin Academy of Music. In 1938, she was enrolled at the University of Warsaw (Faculty of Mathematics and Science). Among her classmates there were well-known personalities like Wanda Szmielew and Roman Sikorski who, after 1945, significantly contributed to the

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development of mathematics and logic in Poland. She had the opportunity to attend lectures of renowned mathematicians such as Waclaw Sierpiński, Kazimierz Kuratowski, Jan Łukasiewicz, and Karol Borsuk.

In 1939, the World War II broke out, and Rasiowa had to interrupt her studies. She established contact with her professors of mathematics and physics at the University of Warsaw and resumed her studies at the underground university in German-occupied Warsaw functioning at significant risk in spite of prohibition by the German occupiers of both secondary and university education. By July 1944, she passed all mandatory exams required for the title of Master of Science in mathematics and prepared her MSc thesis devoted to mathematical logic under the academic supervision of Jan Łukasiewicz. The manuscript of her dissertation was burned during the Warsaw Uprising of 1944. Helena Rasiowa and her mother were miraculously saved after spending numerous days in different cellars, covered by the ruins of houses in the Old City in Warsaw that were destroyed during the bombing. The two women left Warsaw and survived thanks to the help of other members of their family.

When the war ended, Rasiowa rewrote her MSc thesis, and in 1945 she graduated from the University of Warsaw with MSc in mathematics. From September 1945 to November 1946, she worked at the Wojciech Górski's secondary school in Warsaw, pursuing her graduate studies at the Section of the Philosophy of Mathematics, supervised by Andrzej Mostowski. On November 1, 1946, she became the assistant lecturer at the University of Warsaw, where she worked for the rest of her life. During her work at the University of Warsaw, she was granted various academic degrees and titles, and she gradually promoted to academic positions like assistant professor, associate professor, and then full professor. Her first publications, *Axiomatisation d'un système partiel de la théorie de la déduction* and *Sur certaines matrices logiques*, came out in 1947 [7]. In 1950, she received doctorate in mathematics and science based on her PhD thesis, *Algebraic treatment of the functional calculi of Lewis and Heyting*, under the academic supervision of Andrzej Mostowski. The thesis reflects the main theme of her future research on algebraic methods in logic. In 1956 Rasiowa received her academic degree *Doctor of Science in Mathematics* (equivalent to habilitation today) at the Institute of Mathematics of the Polish Academy of Sciences. For the habilitation degree she submitted two papers, *viz.*, *Algebraic models of axiomatic theories* and *Constructive theories*. Together these papers formed a dissertation entitled *Algebraic models of elementary theories and their applications*. Between 1954 and 1957 she held a post of Associate Professor there, jointly with an analogous position at the University, and became Professor in 1957 and subsequently Full Professor in 1967. During that time, she wrote about 20 different papers coauthored by Roman Sikorski, Andrzej Mostowski, Andrzej Białynicki-Birula, and Jerzy Łoś. In 1957, she was granted the title of a Professor by the Central Certifying Board and in 1967, the title of a Full Professor by the Council of State.

As an academic, Helena Rasiowa represented, with pride and dignity, the Polish school of logic, which was popularized during the interwar period by such

scientists as Jan Łukasiewicz, Stanisław Leśniewski, Kazimierz Ajdukiewicz, and Alfred Tarski. Her research from the 1950's (including her PhD dissertation, habilitation thesis and numerous other publications, co-authored by other well-known scientists with whom she worked at that time) led to a deeper understanding of the possibilities related to the use of algebraic and topological methods in logic. These concerned both the classical and non-classical predicate calculus (including intuitionistic logic, modal logics, and many-valued logics). In the academic year of 1949/50, Helena Rasiowa participated in the lectures by Stanisław Mazur, devoted to "constructive" analysis. At that time, she became familiarized with the results of the research on "constructive" models of computation in analysis. That research was initiated between 1936-1939 as part of the collaboration between Stefan Banach and Stanisław Mazur. Later on, Helena Rasiowa and Andrzej Grzegorzcyk [6] published lecture notes out of that lectures.

The interest in algebraic methods of logic (including their applications in theorem proving) and models of computations for identifying constructive fragments of mathematical theories were naturally connected with the research of logical foundations of the emerging computer science and studies in the field of AI (*e.g.*, methods of automatic theorem proving). As a result in 1960's, a group of researchers around Professor Rasiowa started conducting studies in such fields as automatic theorem proving, algorithmic logic and, later in 1970's, program logic, approximate reasoning, and other domains of foundations of computer science. For approximately 30 years, that is till the end of her life, Professor Rasiowa continued that research together with her students and collaborators. Her work helped to open many important projects related to applications of logic in the foundations of computer science. Moreover, together with Zdzisław Pawlak, she founded a scientific journal, known as *Fundamenta Informaticae*, devoted to the foundations of computer science. From the very beginnings of that journal in 1977 till the end of her life, she was its editor-in-chief. Thanks to her unimaginably hard scientific and organizational work, *Fundamenta Informaticae* managed to gain international renown. She was an active Collecting Editor with *Studia Logica* (since 1974) and Associate Editor of the *Journal of Approximate Reasoning* (since 1986).

Her devotion to work bore fruits in the fields of AI and computer science, resulting in the creation of an entire school of students and collaborators, who still continue the research initiated by Rasiowa and Pawlak. The school is sometimes referred to as the Polish Pawlak-Rasiowa School of AI [4].

The establishment and development of the School emphasize considerable contributions of Professor Rasiowa in the development of research devoted to the application of mathematical logic in Computer Science and AI. Much earlier than other mathematicians of her generation, she realized that computer science may be a great inspiration for logic. She also paid attention to the need of research on logical foundations of computer science by actively participating in their development. By 1960's she envisioned the significance of logic for the development of theoretical computer science and AI. She was aware of the facts that numerous scientific problems of theoretical computer science may be solved by methods developed in

logic, and logical research in computer science may constitute an important source of inspiration for the development of logic. Helena Rasiowa inspired to conduct intensive, fruitful research on program logics, methods of reasoning with incomplete information and logical calculi for AI systems. As the head of the Section of Mathematical Logic at the Institute of Mathematics (University of Warsaw), she conducted seminars and research projects devoted to these fields.

It is worth recalling that one of the first great scientists to propose the research on relationships between algebraic systems and logical systems was George Boole (who referred to the ideas formulated by, *e.g.*, Leibniz). The works by Boole and his successors led to the development of the concept of Boolean algebra and helped to establish its relationship with the classical predicate calculus. This relationship is naturally based on an algebraic construction introduced by Lindenbaum and Tarski, based on the equivalence classes generated by formulas. The Stone's representation theorem applied to the Lindenbaum-Tarski algebra contributed to the development of research on topological properties of models for logic.

The second very important algebraic construction, which defines the relationships between logic and algebra, was initiated by the research of Łukasiewicz and Post. This approach treats formulas as algebraic functions over particular algebras. Key algebraic methods in the research concerning intuitionistic logic and modal logic were developed by Marshall Stone, Alfred Tarski, and John McKinsey. Helena Rasiowa became actively involved in this research area. Together with Roman Sikorski, she developed the first algebraic proof of the Gödel's completeness theorem for the classical predicate calculus. Next, she used an algebraic method to prove analogous theorems for the predicate calculus of intuitionistic logic and modal logics. This enabled her to obtain algebraic proofs of a number of other important theorems concerning both classical logic and numerous non-classical logics. Since that moment, numerous logicians and mathematicians in the world have started to use analogous algebraic methods in their research on logical systems.

The first monograph by Helena Rasiowa, *The Mathematics of Metamathematics*, which she co-authored with Roman Sikorski, was published in 1963 [8]. It contains a systematic and comprehensive overview of the results related to the algebras of logical calculi (including classical, intuitionistic, modal, and positive logic). The monograph exerted a profound influence on numerous logicians in the world. Let us quote professor Melvin Fitting [3]:

[...] the ideas were of a sort I had never come across before, and I was enchanted. This way of using algebra, producing known results in classical logic, then applying similar techniques to non-classical logics to get new results—it all seemed like magic. Profound results fell out so effortlessly, it seemed. How could one read this book and remain unaffected?

In the Rasiowa-Sikorski monograph we may find, *e.g.*, a very interesting proof of the Rasiowa-Sikorski lemma, based on a popular (among the representatives

of the Polish School of Mathematics) method of proving existential theorems by means of the Baire category theorem. This method was used by such well-known mathematicians as Stefan Banach, Hugo Steinhaus, and Stanisław Mazur. At the same time, we become familiarized with numerous interesting topological properties of models for the classical predicate calculus. Numerous generalizations of the Rasiowa-Sikorski lemma to other algebraic structures (*e.g.*, Post's algebras, certain types of distributive lattices in the form of the Rauszer-Sabalski lemma) were created. Moreover, there appeared versions of the proof of the Rasiowa-Sikorski lemma that did not use the Baire category theorem.

In *The Mathematics of Metamathematics*, algebraic models for the predicate calculus, introduced by Rasiowa and Sikorski, also are presented. These include Boolean models for the classical predicate calculus and Heyting models for the intuitionistic predicate calculus. Dana Scott and Robert Solovay used the concept of Boolean models to simplify a well-known Cohen's proof of the independence of the axiom of choice, along with Cantor's continuum hypothesis. In this simplification, the key role is played by both Boolean models and the Rasiowa-Sikorski lemma itself [2]. In 1973, Denis Higgs showed that there are some strong relationships between algebraic semantics of Rasiowa and Sikorski and the semantics based on topos of sheaves [2]. Later, these relationships were independently developed by Dana Scott and his students. This led to further modifications of the Cohen's method and its generalizations in topos theory.

Another well-known monograph of Helena Rasiowa, *Algebraic Approach to Non-Classical Logics* [9], presents algebraic theories for a wide class of non-classical logics. It encompasses positive and classical implicational logics, logics weaker than the positive implicational logic, minimal logic, positive logic with semi-negation, constructive logics with strong negations and Post's logics. The aim of the book was to identify a class of logics that is as broad as possible and for which a general algebraic theory could be formulated. The developed theory consists of tools for proving significant theorems about the logics from this class simultaneously for the entire class, and not - as it was treated earlier - separately for each logic.

Helena Rasiowa is the author of about one hundred scientific works and the academic textbook, *viz.*, *The Introduction to Contemporary Mathematics*, which gained popularity both in Poland and abroad. Her works and monographs helped to educate whole generations of logicians in Poland and abroad. In different countries, one can meet scientists who after studying the monographs and works of Professor Helena Rasiowa proudly call themselves her students, despite the fact that they have never met her in person. She educated many generations of students and young academic researchers and was an academic supervisor of nearly twenty PhDs, of which several obtained titles of professors. This includes: Michael Bleicher (1961, Tulane University), Vladimir G. Kirin (1966, University of Zagreb), Andrzej Salwicki (1969), Nguen Cat Ho (1971, Vietnam Academy of Sciences), Cecylia Rauszer (1971), Ewa Orłowska (1971), Grażyna Mirkowska (1972), Maria Semeniuk-Polkowska (1972), Wiktor Bartol (1973), Antoni Kreczmar (1973), Jerzy

Tiurny (1975), Lech Banachowski (1975), Anita Wasilewska (1975), Michał Krynicki (1976), Bolesław Szymański (1976), Dimiter Vakarelov (1977, Sofia University), Bogdan Sabalski (1977), Halina Przymusińska (1979), and Leszek Rudak (1986).

The extremely high position of Helena Rasiowa within the international scientific environment resulted in numerous invitations from the best universities and research centers in Europe and both Americas. She gave lectures, including frequent plenary lectures, during numerous international congresses and conferences. She also chaired many scientific sessions.

During her last two years of life, Helena Rasiowa, not succumbing to the aggravating disease, continued working on her new monograph, *Algebraic models of logics*, of which she is the author of 8 chapters [10]. In June 1994, she started the preparation of a special edition of *Studia Logica*, entitled *Reasoning with Incomplete Information*, and, in particular, prepared the list of its topics.

The readers are referred to [1] for additional details on the scientific achievements of Helena Rasiowa, in particular for the full list of her publications.

It should be emphasized that despite of her significant scientific activity, Professor Rasiowa did not refuse taking various roles that were important for the scientific and academic life. The university was her second home. She was a person of great perseverance. In retrospect, it is amazing to realize how she was able to meet all these challenges.

From 1955 to 1958, she was the Director of the Extramural Studies at the Institute of Mathematics (University of Warsaw). From 1964 to 1970, she headed the Section of the Foundations of Mathematics at the University of Warsaw and from 1970 till the end of her life, she was the head of the Section of Mathematical Logic at the same university. For more than 15 years she was the Dean of the Faculty of Mathematics, Computer Science and Mechanics (1958-1960, 1962-1966, 1968-1978). She also represented the Faculty Council of the Faculty of Mathematics, Computer Science and Mechanics to the Senate of the University of Warsaw. Helena Rasiowa actively participated in the scientific life and performed a number of important functions in academic organizations and associations both in Poland and abroad. From 1961 to 1968, she was a Scientific Secretary of the Institute of Mathematics of Polish Academy of Sciences, and later, of its board member. From 1970 to 1972 she was the member of the Committee of Mathematical Assessors at the Central Council of Higher Education and from 1968 to 1972 she was a Chairperson of the Committee of Mathematical Assessors for Teacher's Colleges. Professor Rasiowa was active in the Polish Mathematical Society (PMS). In PMS, she was a member of the board in the Warsaw Chapter, responsible for the popularization of mathematics and training of teachers. She was appointed as the President of the Warsaw Chapter of PMS twice (1957-1958, 1963-1964) and she was also the Secretary of the Society (1955-1956) and its Vice-President (1958) as well. In the Association for Symbolic Logic, she was a Council member (1958-1960) and a member of the Executive Committee for Foreign Affairs (1972-1974). In 1972, she was an Alternate Assessor (1972-1975) and Assessor (1975-1979) in

the Division of Logic, Methodology and Philosophy of Science of the International Union of History and Philosophy of Sciences. For several years, she was the Chairperson of the Scientific Council of Computational Center by the Polish Academy of Sciences and later of the Institute of the Foundations of Computer Science of the Academy, as well.

Thanks to her active participation, efforts aimed at the creation of the *Polish Association for Logic and Philosophy of Science* were undertaken between 1980-1981. This association is the continuation of the Polish Logic Society, founded on April 22, 1936 by Jan Łukasiewicz and Alfred Tarski. The creation of the society, whose aim was to “practice and nurture logic and methodology, along with their history, didactics and possible application,” was connected with a great development of logic in the interwar Poland. The Polish Logical Society was the second organization of this type in the world (after the Association for Symbolic Logic in the USA). After the war, the society was not reactivated. The efforts aimed at the creation of a similar society in 1980-1981 turned out futile as the authorities refused to register it. During the IX International Congress of Logic and Philosophy of Science in Uppsala in 1991, a group of Polish congress participants met to initiate the establishment of the association. On December 10, 1991, a constituent meeting of the Polish Association for Logic and Philosophy of Science took place.

It is possible to identify numerous areas of contemporary research, which are directly or indirectly inspired by the works of Helena Rasiowa. These include algebraic methods in logic, deductive systems like tableau, mathematical foundations of computer science, and artificial intelligence (including approximate reasoning and interactive granular computations).

Helena Rasiowa was an extremely hard-working, friendly and cheerful person, who has been always kind and sensitive to human problems with great intelligence. She was always ready to help, not only as a scientist, but also as a human being in real-life problems. In each, even most difficult situation, she tried to do as much good as possible - this was her life motto as an academic teacher, devoted wholeheartedly to logic and Polish science.

She was able to share the love for her children, Krystyna Kijewska and Zbigniew Ras, with the love for mathematics.

Professor Helena Rasiowa was a Franciscan tertiary, a fact which, during her life, was known only to some of her loved ones. The faith combined with a passion for mathematics, enabled her to survive the most difficult moments, like the war or the very last stage of her life, when the incurable disease began to destroy her. This was a great lesson for her students about how to behave in the most difficult situations.

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