

Mathematical  
Discovery on  
Understanding,  
Learning and Teaching  
Problem Solving

VOLUMES I AND II

George Polya

# Mathematical Discovery On Understanding Learning And Teaching Problem Solving

**Therese Keane, Cathy Lewin, Torsten  
Brinda, Rosa Bottino**



## **Mathematical Discovery On Understanding Learning And Teaching Problem Solving:**

*Mathematical Discovery on Understanding, Learning, and Teaching Problem Solving* George Pólya, Sam Sloan, 2009  
Solving problems writes Polya is a practical art like swimming or skiing or playing the piano You can learn it only by imitation and practice This book cannot offer you a magic key that opens all the doors and solves all the problems but it offers you good examples for imitation and many opportunities for practice If you wish to learn swimming you have to go into the water and if you wish to become a problem solver you have to solve problems In enough cases to allay discouragement over not immediately discovering a solution Professor Polya masterfully leads the reader down several unproductive paths At the end of each chapter he provides examples for the reader to solve By means of these carefully selected and arranged problems many of them directly related to others that precede and guided by just the right suggestions at just the proper time the reader's own ability is developed and extended Solutions to the examples and in many cases outlines of procedures for discovering solutions are given at the back of the book With striking promise for effectiveness the entire book as a unit is one great experience in learning processes for problem solving through participation The author has captured with great success the implication of his basic premise stated in the preface The Mathematics Teacher *Mathematical Discovery*, 1962

Mathematical Discovery George Pólya, 1962 Mathematical Discovery George Pólya, 1962 Mathematical Discovery on Understanding, Learning and Teaching Problem Solving, Volumes I and II George Polya, 1981-04-24 A unique heuristic approach to mathematical discovery and problem solving This combined edition of *Mathematical Discovery On Understanding Learning and Teaching Problem Solving* is unique among mathematics texts Espousing a heuristic approach to mathematical problem solving the text may be followed sequentially or according to instructors individualized curricula Beginning with a discussion of patterns and practical approaches to problem solving the book then presents examples from various branches of math and science to help students discover how to solve problems on their own an invaluable skill for the classroom and beyond **Mathematical Discovery** George Polya, 1962 Mathematical Discovery Gareth Thomas, 1962

**Mathematical Discovery. On Understanding, Learning, and Teaching Problem Solving. Volume II** George Polya, 1965 **Mathematical Discovery Vol II.** George Pólya, 1965 Mathematical discovery. bd. 1-2 on understanding, learning and teaching problem solving George Polya, 1965 Implementation Research on Problem Solving in School Settings Inga Gebel, 2019 Content of the Book The University of Potsdam hosted the 25th ProMath and the 5th WG Problem Solving conference Both groups met for the second time in this constellation which contributed to profound discussions on problem solving in each country taking cultural particularities into account The joint conference took place from 29th to 31st August 2018 with participants from Finland Germany Greece Hungary Israel Sweden and Turkey The conference revolved around the theme Implementation research on problem solving in school settings These proceedings contain 14 peer reviewed research and practical articles including a plenary paper from our distinguished colleague Anu Laine In addition

the proceedings include three workshop reports which likewise focused on the conference theme As such these proceedings provide an overview of different research approaches and methods in implementation research on problem solving in school settings which may help close the gap between research and practice and consequently make a step forward toward making problem solving an integral part of school mathematics on a large scale

CONTENT PLENARY REPORT Anu Laine How to promote learning in problem solving pp 3 18 This article is based on my plenary talk at the joint conference of ProMath and the GDM working group on problem solving in 2018 The aim of this article is to consider teaching and learning problem solving from different perspectives taking into account the connection between 1 teacher s actions and pupils solutions and 2 teacher s actions and pupils affective reactions Safe and supportive emotional atmosphere is base for students learning and attitudes towards mathematics Teacher has a central role both in constructing emotional atmosphere and in offering cognitive support that pupils need in order to reach higher level solutions Teachers need to use activating guidance i e ask good questions based on pupils solutions Balancing between too much and too little guidance is not easy [https://doi.org/10.37626/GA9783959871167\\_0\\_01](https://doi.org/10.37626/GA9783959871167_0_01)

RESEARCH REPORTS AND ORAL COMMUNICATIONS Lukas Baumanns and Benjamin Rott Is problem posing about posing problems A terminological framework for researching problem posing and problem solving pp 21 31 In this literature review we critically compare different problem posing situations used in research studies This review reveals that the term problem posing is used for many different situations that differ substantially from each other For some situations it is debatable whether they provoke a posing activity at all For other situations we propose a terminological differentiation between posing routine tasks and posing non routine problems To reinforce our terminological specification and to empirically verify our theoretical considerations we conducted some task based interviews with students [https://doi.org/10.37626/GA9783959871167\\_0\\_02](https://doi.org/10.37626/GA9783959871167_0_02)

Kerstin Bruning Long term study on the development of approaches for a combinatorial task pp 33 50 In a longitudinal research project over two years we interviewed children up to 6 times individually to trace their developmental trajectories when they solve several times the same tasks from different mathematical areas As a case study I will present the combinatorial task and analyze how two children a girl and a boy over two years approached it As a result of the case studies we can see that the analysis of the data product oriented or process oriented provides different results It is also observable that the developmental trajectory of the girl is a more continuous learning process which we cannot identify for the boy [https://doi.org/10.37626/GA9783959871167\\_0\\_03](https://doi.org/10.37626/GA9783959871167_0_03)

Lars Burman Developing students problem solving skills using problem sequences Student perspectives on collaborative work pp 51 59 Using problem solving in mathematics classrooms has been the object of research for several decades However it is still necessary to focus on the development of problem solving skills and in line with the recent PISA assessment more attention is given to collaborative problem solving This article addresses students collaborative work with problem sequences as a means to systematically develop students problem solving skills The article offers student perspectives on challenges concerning the social atmosphere differentiation

on teaching and learning in cooperation In spite of the challenges the students experiences indicate that the use of problem sequences and group problem solving can be fruitful in mathematics education <https://doi.org/10.37626/GA9783959871167.004> Alex Friedlander Learning algebraic procedures through problem solving pp 61–69 In this paper I attempt to present several examples of tasks and some relevant findings that investigate the possibility of basing a part of the practice oriented tasks on higher level thinking skills that are usually associated with processes of problem solving The tasks presented and analysed here integrate problem solving components namely reversed thinking expressing and analysing patterns and employing multiple solution methods into the learning and practicing of algebraic procedures such as creating equivalent expressions and solving equations <https://doi.org/10.37626/GA9783959871167.005> Thomas Gawlick and Gerrit Welzel Backwards or forwards Direction of working and success in problem solving pp 71–89 We pose ourselves the question What can one infer from the direction of working when solvers work on the same task for a second time This is discussed on the basis of 44 problem solving processes of the TIMSS task K10 A natural hypothesis is that working forwards can be taken as evidence that the task is recognized and a solution path is recalled This can be confirmed by our analysis A surprising observation is that when working backwards pivotal for success is in case of K10 to change to working forwards soon after reaching the barrier <https://doi.org/10.37626/GA9783959871167.006> Inga Gebel Challenges in teaching problem solving Presentation of a project in progress by using an extended tetrahedron model pp 91–109 In order to implement mathematical problem solving in class it is necessary to consider many different dimensions the students the teacher the theoretical demands and adequate methods and materials In this paper an implementation process is presented that considers the above dimensions as well as the research perspective by using an extended tetrahedron model as a structural framework In concrete terms the development and initial evaluation of a task format and a new teaching concept are presented that focus on differentiated problem solving learning in primary school The pilot results show initial tendencies towards possible core aspects that enable differentiated problem solving in mathematics teaching <https://doi.org/10.37626/GA9783959871167.007> Heike Hagelgans Why does problem oriented mathematics education not succeed in an eighth grade An insight in an empirical study pp 111–119 Based on current research findings on the possibilities of integration of problem solving into mathematics teaching the difficulties of pupils with problem solving tasks and of teachers to get started in problem solving this article would like to show which concrete difficulties delayed the start of the implementation of a generally problem oriented mathematics lesson in an eighth grade of a grammar school The article briefly describes the research method of this qualitative study and identifies and discusses the difficulties of problem solving in the examined school class In a next step the results of this study are used to conceive a precise teaching concept for this specific class for the introduction into problem oriented mathematics teaching <https://doi.org/10.37626/GA9783959871167.008> Zoltán Kovács and Eszter Kónya Implementing problem solving in mathematics classes pp 121–128 There is little evidence of teachers are using challenging

problems in their mathematics classes in Hungary At the University of Debrecen and University of Ny regyh za we elaborated a professional development program for inservice teachers in order to help them implementing problem solving in their classes The basis of our program is the teacher and researcher collaboration in the lessonplanning and evaluation In this paper we report some preliminary findings concerning this program <https://doi.org/10.37626/GA9783959871167.0.09> Ana Kuzle Campus school project as an example of cooperation between the University of Potsdam and schools pp 129 141 The Campus School Project is a part of the Qualit tsoffensive Lehrerbildung project whose aim is to improve and implement new structures in the university teacher training by bringing all the essential protagonists namely university stuff preservice teachers and in service teachers together and having them work jointly on a common goal The department of primary mathematics education at the University of Potsdam has been a part of the Campus School Project since 2017 Thus far several cooperations emerged focusing on different aspects of problem solving in primary education Here I give an overview of selected cooperations and the first results with respect to problem solving research in different school settings <https://doi.org/10.37626/GA9783959871167.0.10> Ioannis Papadopoulos and Aikaterini Diakidou Does collaborative problem solving matter in primary school The issue of control actions pp 143 157 In this paper we follow three Grade 6 students trying to solve at first individually and then in a group arithmetical and geometrical problems The focus of the study is to identify and compare the various types of control actions taken during individual and collaborative problem solving to show how the collective work enhances the range of the available control actions At the same time the analysis of the findings give evidence about the impact of the collaborative problemsolving on the way the students can benefit in terms of aspects of social metacognition <https://doi.org/10.37626/GA9783959871167.0.11> Sarina Scharnberg Adaptive teaching interventions in collaborative problem solving processes pp 159 171 Even though there exists limited knowledge on how exactly students acquire problem solving competences researchers agree that adaptive teaching interventions have the potential to support students autonomous problem solving processes However most recent research aims at analyzing the characteristics of teaching interventions rather than the interventions effects on the students problem solving process The study in this paper addresses this research gap by focusing not only on the teaching interventions themselves but also on the students collaborative problem solving processes just before and just after the interventions The aim of the study is to analyze the interventions effect on the learners integrated problem solving processes <https://doi.org/10.37626/GA9783959871167.0.12> Nina Sturm Self generated representations as heuristic tools for solving word problems pp 173 192 Solving non routine word problems is a challenge for many primary school students A training program was therefore developed to help third grade students to find solutions to word problems by constructing external representations e g sketches tables and to specifically use them The objective was to find out whether the program positively influences students problemsolving success and problem solving skills The findings revealed significant differences between trained and untrained classes Therefore it can be

assumed that self generated representations are heuristic tools that help students solve word problems This paper presents the results on the impact of the training program on the learning outcome of students [https://doi.org/10.37626/GA9783959871167\\_013](https://doi.org/10.37626/GA9783959871167_013) Kinga Szcs Problem solving teaching with hearing and hearing impaired students pp 193 203 In the last decade the concept of inclusion has become more and more prevalent in mathematics education especially in Germany Accordingly teachers in mathematics classrooms have to face a wide range of heterogeneity which includes physical sensory and mental disabilities At the Friedrich Schiller University of Jena within the framework of the project Media in mathematics education it is examined how new technologies can support teaching in inclusive mathematics classrooms In the academic year 2017 18 the heterogeneity regarding hearing impairment was mainly focussed on Based on a small case study with hearing and hearing impaired students a problem solving unit about tangent lines was worked out according to Plya which is presented in the paper [https://doi.org/10.37626/GA9783959871167\\_014](https://doi.org/10.37626/GA9783959871167_014) WORKSHOP REPORTS Ana Kuzle and Inga Gebel Implementation research on problem solving in school settings A workshop report 207 On the last day of the conference we organized a 90 minute workshop The workshop focused on the conference theme Implementation research on problem solving in school settings Throughout the conference the participants were invited to write down their questions and or comments as a response to held presentations [https://doi.org/10.37626/GA9783959871167\\_015](https://doi.org/10.37626/GA9783959871167_015) Ana Kuzle Inga Gebel and Anu Laine Methodology in implementation research on problem solving in school settings pp 209 211 In this report a summary is given on the contents of the workshop In particular the methodology and some ethical questions in implementation research on problem solving in school settings are discussed The discussion showed how complex this theme is so that many additional questions emerged [https://doi.org/10.37626/GA9783959871167\\_016](https://doi.org/10.37626/GA9783959871167_016) Lukas Baumanns and Sarina Scharnberg The role of protagonists in implementing research on problem solving in school practice pp 213 214 Based on seminal works of Plya 1945 and Schoenfeld 1985 problem solving has become a major focus of mathematics education research Even though there exists a variety of recent research on problem solving in schools the research results do not have a direct impact on problem solving in school practice Instead a dissemination of research results by integrating different protagonists is necessary Within our working group the roles of three different protagonists involved in implementing research on problem solving in school practice were discussed namely researchers pre service and in service teachers by examining the following discussion question To what extent do the different protagonists enable implementation of research findings on problem solving in school practice [https://doi.org/10.37626/GA9783959871167\\_017](https://doi.org/10.37626/GA9783959871167_017) Benjamin Rott and Ioannis Papadopoulos The role of problem solving in school mathematics pp 215 217 In this report of a workshop held at the 2018 ProMath conference a summary is given of the contents of the workshop In particular the role of problem solving in regular mathematics teaching was discussed problem solving as a goal vs as a method of teaching with implications regarding the selection of problems its implementation into written exams as well as teacher proficiency that is needed for implementing problem solving into

mathematics teaching <https://doi.org/10.37626/GA9783959871167.0.18>

## **Fundamental Constructs in Mathematics**

**Education** Sue Johnston-Wilder, John Mason, 2004-01-22 *Fundamental Constructs in Mathematics Education* is a unique sourcebook which has been crafted from a collection of classic tasks extracts and texts that have been quoted repeatedly in mathematics education literature. Linked together by the editors' narrative, the book provides a fascinating examination of key constructs in mathematics education. The book is divided into two parts. The first part examines thinking about the learner and includes the following constructs: constructivism, activity theory, and didactics. Beginning with a chapter dedicated to the classic tasks used by researchers to probe learners' understanding, readers are encouraged to try these theories themselves with learners and be knowledgeable when they encounter them in other writing. The second part focuses on thinking and teaching and includes issues of getting started, keeping going, and bringing to a conclusion. Bringing together writing from Balacheff, Brousseau, Bruner, Cobb, Comfrey, Freudenthal, Greeno, Marton, Piaget, Schon, Vygotsky, and many others, this unique examination of constructs in mathematics education will be a valuable resource for anyone reading literature related to learning mathematics, be they a teacher, adviser, or a student on a masters or PhD course. [Towards a Collaborative Society Through Creative Learning](#) Therese Keane, Cathy Lewin, Torsten Brinda, Rosa Bottino, 2023-09-27 This book contains the revised selected refereed papers from the IFIP World Conference on Computers in Education on Towards a Collaborative Society through Creative Learning WCCE 2022 Hiroshima Japan August 20-24, 2022. A total of 61 papers (54 full papers and 7 short papers) were carefully reviewed and selected from 131 submissions. They were organized in topical sections as follows: Digital Education and Computing in Schools; Digital Education and Computing in Higher Education; National Policies and Plans for Digital Competence. [General Technical Report NC. ,1981](#) [Learning Mathematics](#) Prof Leone Burton, Leone Burton, 2012-10-12 *Learning Mathematics* brings together a collection of interrelated and forward-looking chapters by internationally recognized experts that explores changes in the theories and practices of learning and teaching mathematics. The authors reject a traditional transmission view of the teaching of mathematics which has proved so ineffective for learning. In its place, they offer information gathered from research and from practice about effects on the learners seeking to create and negotiate meaning. Learners are presented as actively attempting to make sense of the mathematics they encounter, and learners, teachers, and researchers are offered examples of how such sense-making activities incorporated into mathematics classrooms impact on coming to know. The book celebrates both diversity in the range of different perspectives, contributions, and topics, and unity in the linking chapters and themes. It will be fascinating reading for those mathematics educators who are eager to engage with a socio-cultural perspective in order to better understand the complexity of learning mathematics. [Discovering New Knowledge about Trees and Forests ,1989](#) [Northern Wisconsin Snowmobilers](#) Earl C. Leatherberry, 1976 *Teaching Computational Thinking in Primary Education* Ozcinar, Huseyin, Wong, Gary, Ozturk, H. Tugba, 2017-10-31 Computational technologies have been impacting human life for years. Teaching methods must adapt



accordingly to provide the next generation with the necessary knowledge to further advance these human assistive technologies Teaching Computational Thinking in Primary Education is a crucial resource that examines the impact that instructing with a computational focus can have on future learners Highlighting relevant topics that include multifaceted skillsets coding programming methods and digital games this scholarly publication is ideal for educators academicians students and researchers who are interested in discovering how the future of education is being shaped International Handbook of Research in History, Philosophy and Science Teaching Michael R. Matthews, 2014-07-03 This inaugural handbook documents the distinctive research field that utilizes history and philosophy in investigation of theoretical curricular and pedagogical issues in the teaching of science and mathematics It is contributed to by 130 researchers from 30 countries it provides a logically structured fully referenced guide to the ways in which science and mathematics education is informed by the history and philosophy of these disciplines as well as by the philosophy of education more generally The first handbook to cover the field it lays down a much needed marker of progress to date and provides a platform for informed and coherent future analysis and research of the subject The publication comes at a time of heightened worldwide concern over the standard of science and mathematics education attended by fierce debate over how best to reform curricula and enliven student engagement in the subjects There is a growing recognition among educators and policy makers that the learning of science must dovetail with learning about science this handbook is uniquely positioned as a locus for the discussion The handbook features sections on pedagogical theoretical national and biographical research setting the literature of each tradition in its historical context It reminds readers at a crucial juncture that there has been a long and rich tradition of historical and philosophical engagements with science and mathematics teaching and that lessons can be learnt from these engagements for the resolution of current theoretical curricular and pedagogical questions that face teachers and administrators Science educators will be grateful for this unique encyclopaedic handbook Gerald Holton Physics Department Harvard University This handbook gathers the fruits of over thirty years research by a growing international and cosmopolitan community Fabio Bevilacqua Physics Department University of Pavia

**Constructing Knowledge for Teaching Secondary Mathematics** Orit Zaslavsky, Peter Sullivan, 2011-04-11 Teacher education seeks to transform prospective and or practicing teachers from neophyte possibly uncritical perspectives on teaching and learning to more knowledgeable adaptable analytic insightful observant resourceful reflective and confident professionals ready to address whatever challenges teaching secondary mathematics presents This transformation occurs optimally through constructive engagement in tasks that foster knowledge for teaching secondary mathematics Ideally such tasks provide a bridge between theory and practice and challenge surprise disturb confront extend or provoke examination of alternatives drawn from the context of teaching We define tasks as the problems or activities that having been developed evaluated and refined over time are posed to teacher education participants Such participants are expected to engage in these tasks collaboratively

energetically and intellectually with an open mind and an orientation to future practice The tasks might be similar to those used by classroom teachers e g the analysis of a graphing problem or idiosyncratic to teacher education e g critique of videotaped practice This edited volume includes chapters based around unifying themes of tasks used in secondary mathematics teacher education These themes reflect goals for mathematics teacher education and are closely related to various aspects of knowledge required for teaching secondary mathematics They are not based on the conventional content topics of teacher education e g decimals grouping practices but on broad goals such as adaptability identifying similarities productive disposition overcoming barriers micro simulations choosing tools and study of practice This approach is innovative and appeals both to prominent authors and to our target audiences

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