Problems and Problem Solving in Chemistry Education

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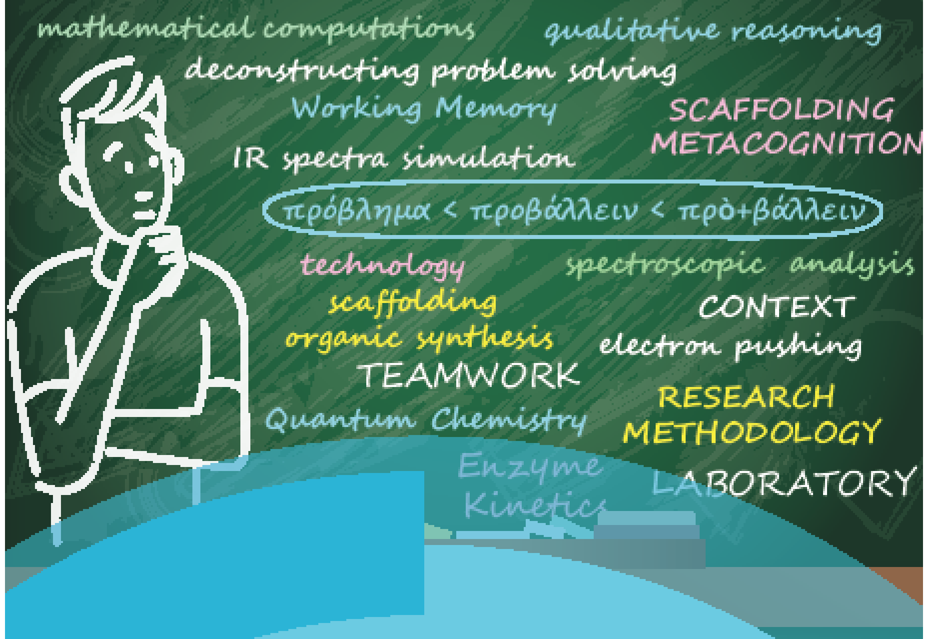
Royal Society of Chemistry



Advances in Chemistry Education Series

Problems and Problem Solving in Chemistry Education

Analysing Data, Looking for Patterns and Making Deductions

Edited by Georgios Tsaparlis

ROYAL SOCIETY OF CHEMISTRY

Problem solving

Contributes to:

- synthesis,
- spectroscopy,
- theory,
- analysis,
- and the characterization of compounds.

Central to the teaching and learning of chemistry at secondary, tertiary and post-tertiary levels of education.

- real problems versus algorithmic exercises

- the differences in approach to problem solving exhibited between experts and novices

Foreword

George Bodner

Preface

Georgios Tsaparlis

Chapter 1 Introduction – The Many Types and Kinds of Chemistry Problems

Georgios Tsaparlis

PART I: GENERAL ISSUES IN PROBLEM SOLVING IN CHEMISTRY EDUCATION

- **Chapter 2 Qualitative Reasoning in Problem-solving in Chemistry**

Vicente Talanquer

- Qualitative reasoning helps to build inferences based on the analysis of qualitative values (e.g., high, low, weak, and strong) of the properties and behaviors of the components of a system, and the application of structure–property relationships.
- The chapter summarizes core findings from research in chemistry education on the challenges that students face when engaging in this type of reasoning, and the strategies that support their learning in this area.

Chapter 3 Scaffolding Metacognition and Resource Activation During Problem Solving: A Continuum Perspective

Nicole Graulich, Axel Langner, Vo Kimberly and Elizabeth Yuriev

- Chemical problem solving relies on conceptual knowledge and the deployment of metacognitive problem solving processes, but novice problem solvers often grapple with both challenges simultaneously.
- Multiple scaffolding approaches have been developed to support student problem solving, often designed to address specific aspects or content area.
- Providing students with opportunities to reflect on the problem solving work of others – peers or experts – can also be of benefit in deepening students' conceptual reasoning skills.

Chapter 4 Deconstructing the Problem-solving Process: Beneath Assigned Points and Beyond Traditional Assessment

Ozcan Gulacar, Charlie Cox and Herb Fynewever

- A central theme: the multitude of ways in which students can be unsuccessful when trying to solve problems.
- Each step of a multi-step problem can be labeled as a subproblem and represents content that students need to understand and use to be successful with the problem.
- The authors have developed a set of codes to categorize each student's attempted solution for every subproblem as either successful or not, and if unsuccessful, identifying why, thus providing a better understanding of common barriers to success, illustrated in the context of stoichiometry

Chapter 5 It Depends on the Problem and on the Solver: An Overview of the Working Memory Overload Hypothesis, Its Applicability and Its Limitations

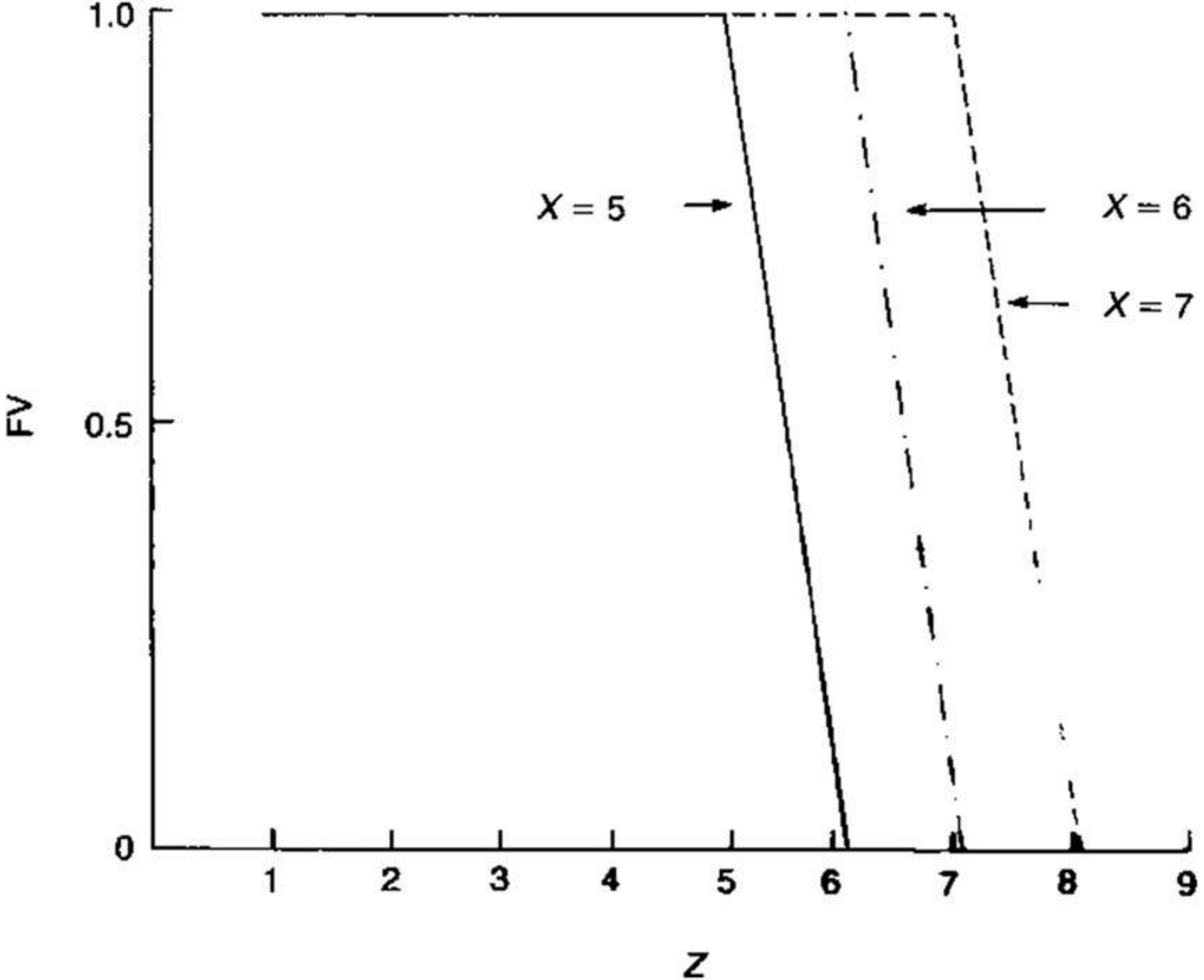
Georgios Tsaparlis

Re-examines the ‘‘working memory overload hypothesis’’ and the associated with it the Johnstone–El Banna predictive model of problem solving.

This famous predictive model is based on the effect of information processing, especially of working-memory capacity on problem solving.

Other factors include:

- mental capacity or M-capacity,
- degree of field dependence/independence,
- and developmental level/scientific reasoning.



1.0
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0
FV
X = 5
X = 6
X = 7
1
2
3
4
5
6
7
8
9
Z

PART II: PROBLEM SOLVING IN ORGANIC CHEMISTRY AND BIOCHEMISTRY

- Chapter 6 Mechanistic Reasoning Using the Electron-pushing Formalism
  Gautam Bhattacharyya

MR (Mechanistic Reasoning) using the EPF (Electron-Pushing Formalism) incorporates several other forms of reasoning, and is also considered as a useful transferrable skill for the biomedical sciences and allied fields.

- **Chapter 7 Scaffolding Synthesis Skills in Organic Chemistry**

Alison B. Flynn

Describes the strategies used by students who have been successful in solving synthetic problems. Associated classroom and problem set activities are also described.

- **Chapter 8 Problem Solving Using NMR and IR Spectroscopy for Structural Characterization in Organic Chemistry**

Megan C. Connor and Ginger V. Shultz

- Reviews studies that have investigated reasoning and problem solving approaches used to evaluate NMR and IR spectroscopic data for organic structural determination, and provides a foundation for understanding how this problem solving expertise develops and how instruction may facilitate such learning.
- The aim is to present the current state of research, empirical insights into teaching and learning this practice, and trends in instructional innovations.

- **Chapter 9 Assessing System Ontology in Biochemistry: Analysis of Students' Problem Solving in Enzyme Kinetics**

Jon-Marc G. Rodriguez, Sven J. Philips, Nicholas P. Hux and Marcy H. Towns

The subject of the study is chemical kinetics in biochemistry, and especially of the action and mechanisms of inhibition agents in enzyme catalysis, where a sophisticated understanding requires students to learn to reason using probability-based reasoning.

PART III: CHEMISTRY PROBLEM SOLVING IN SPECIFIC CONTEXTS

- **Chapter 10 Problem Solving in the Chemistry Teaching Laboratory: Is This Something That Happens?**

Ian Hawkins, Vichuda K. Hunter, Michael J. Sanger and Amy J. Phelps

- **Emphasis on the practice of problem solving skills beyond those of an algorithmic mathematical nature.**
- **A departure from the procedural skills training often associated with the reason we engage in laboratory work (learning to titrate for example).**
- **If part of what we are doing in undergraduate chemistry courses is to prepare students to go on to undertake research, somewhere in the curriculum there should be opportunities to practice solving problems that are both open-ended and laboratory-based.**
- **The history of academic chemistry laboratory practice is reviewed and its current state considered.**

- **Chapter 11 Problems and Problem Solving in the Light of Context-based Chemistry**

Karolina Broman

- Focuses on chemistry problems and problem solving by employing context-based learning approaches, where open-ended problems focusing on higher-order thinking are explored.
- Chemistry teachers suggested contexts that they thought their students would find interesting and relevant, e.g., chocolate, doping, and dietary supplements

- **Chapter 12 Using Team Based Learning to Promote Problem Solving Through Active Learning**

Natalie J. Capel, Laura M. Hancock, Chloe Howe, Graeme R. Jones, Tess R. Phillips and Daniela Plana

- TBL is a structured small group collaborative form of learning, where learners are required to prepare for sessions in advance, then discuss and debate potential solutions to problems with their peers.
- It has been found to be highly effective at facilitating active learning.
- The authors describe their experience with embedding TBL into their chemistry curricula at all levels, including a transnational degree program with a Chinese university.

PART IV: NEW TECHNOLOGIES IN PROBLEM SOLVING IN CHEMISTRY

- **Chapter 13 Technology, Molecular Representations, and Student Understanding in Chemistry**

Jack D. Polifka, John Y. Baluyut and Thomas A. Holme

- The ability of students to learn and value aspects of the chemistry curriculum that delve into the molecular basis of chemical events relies on the use of models/molecular representations, and enhanced awareness of how these models connect to chemical observations.
- Molecular representations in chemistry focus on technology solutions that enhance student understanding and learning of these conceptual aspects of chemistry.

- **Chapter 14 An Educational Software for Supporting Students' Learning of IR Spectral Interpretation**

Maria Limniou, Nikos Papadopoulos, Dimitris Gavril, Aikaterini Touni and Markella Chatziapostolidou

- The software includes a wide range of chemical compounds supported by real IR spectra, allowing students to learn how to interpret an IR spectrum, via a step by step process.
- The chapter includes a report on a pilot trial with a small-scale face-to-face learning environment.
- The software is available on the Internet for everyone to download and use.

- **Chapter 15 Exploring Chemistry Problems with Computational Quantum Chemistry Tools in the Undergraduate Chemistry Curriculum**

Michael P. Sigalas

- Explores the use of computational chemistry for the study of chemical phenomena, and the prediction and interpretation of experimental data, from thermodynamics and isomerism, to reaction mechanisms and spectroscopy.
- The pros and cons of a series of software tools for building molecular models, preparation of input data for standard software, and visualization of computational results are discussed.

PART V: NEW PERSPECTIVES FOR PROBLEM SOLVING IN CHEMISTRY EDUCATION

- **Chapter 16 Methodological and Epistemological Issues in Science Education Problem-solving Research: Linear and Nonlinear Paradigms**

Dimitrios Stamovlasis and Julie Vaiopoulou

- Following a short review of the relevant literature with emphasis on methodology and the statistical modeling used, the weak points of the traditional approaches are discussed and a novel epistemological framework based on complex dynamical system theory is described.
- Research using catastrophe theory provides empirical evidence for these phenomena by modeling and explaining mental overload effects and students' failures.
- Examples of the application of this theory to chemistry problem solving is reviewed.

- Chapter 17 Issues, Problems and Solutions: Summing It All Up

Georgios Tsaparlis

- Chapter 18 Postscript – Two Issues for Provocative Thought:

(a) The Potential Synergy Between HOTS and LOTS

(b) When Problem Solving Might Descend to Chaos Dynamics

Georgios Tsaparlis

The Potential Synergy Between HOTS and LOTS: The Case of the Fight against COVID-19

Higher and Lower-order Thinking Skills (HOTS and LOTS)

- The difference: not a dichotomy nor a marker of higher or lower intelligence.

In practice: the ability to employ both HOTS and LOTS is very useful and may even be essential.

- Good to employ and develop HOTS, it is even better to combine both HOTS and LOTS.

- Algorithms, dealing with LOTS-type problems, can often be demanding and may have initially required both HOTS and extensive practice to achieve the level of expertise necessary to create the algorithm.

- The availability and application of complex algorithms and smart technologies have been necessary for the solution of a range of important problems

- The very existence and application of these algorithmic procedures require the development of conceptual, computational and technical solutions to general or more specific problems.

The current coronavirus (COVID-19) pandemic

- the structure of SARS-CoV-2;
- appropriate tests for monitoring the appearance and spreading of COVID-19;
- identifying, detecting and measuring antibodies offering protection in the human body;
- developing appropriate, effective, and safe drugs and vaccines that will protect the world's population;
- and so prepare the world to deal better with any new pandemic which might inflict the world in the (hopefully) very far future.

American Chemical Society:

“Chemistry has a key role to play in understanding everything from viral structure to pathogenesis, isolation of vaccines and therapies, as well as in the development of materials and techniques used by basic researchers, virologists and clinicians”.

Σας ευχαριστώ