Success Conditions of Effective Problem Solving in Physics and Chemistry Education: A Systematic Review

Adrian Schmidt[†*], Rüdiger Tiemann[†], Gunnar Friege[*]

Theory

Background
- Technological and social developments lead to adaptation of the skills necessary for social and economic participation - especially in STEM education.
- Problem solving (PS) is particularly relevant as one of the 21st Century Skills (as part of Critical Thinking).

Research Gap
- More studies needed on new types of instruction such as productive failure, problem-based learning etc. [1],
- Lack of studies on the bandwidth-accuracy dilemma: general strategies for many problems vs. specific solution strategy for specific problems,
- Hardly any physics and/or chemistry specific studies [2,3],
- Lack of clarity on use of new technologies [4,5].

Research Question & Methods

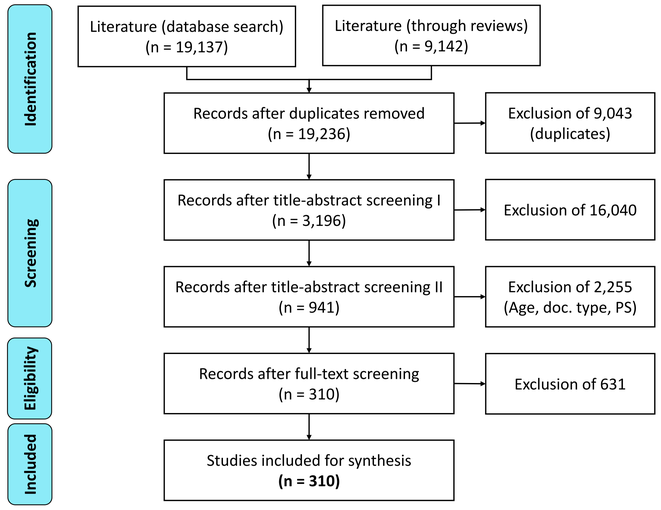
1. How has problem solving in chemistry and physics education changed in the wake of changing demands on science education (e.g., easier use of digital tools, but also changing global challenges)?

2. Can generalizable approaches to effective problem solving in chemistry and physics education be identified that can be transferred as indicators of success in a STEM-friendly educational environment?

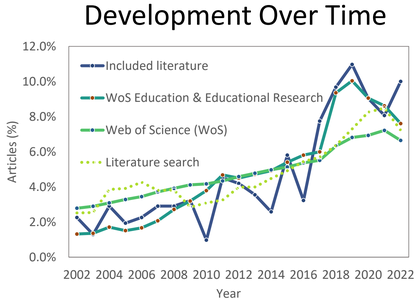
Final inclusion criteria:
(1) Topic of "problem solving"; (2) context of physics or chemistry education; (3) study population is high school/secondary school (ages 10-18); (4) written in English; (5) published in the years 2002-2022.

Databases & Journals:
Web of Science, Scopus, ERIC, FIS, APA PsychINFO, Taylor Francis;
American Journal of Physics, Physics Review Physics Education Research, Journal of Research in Science Teaching, Science Education, International Journal of Mathmatics and Science Teaching.

PRISMA Flow Diagram [6]



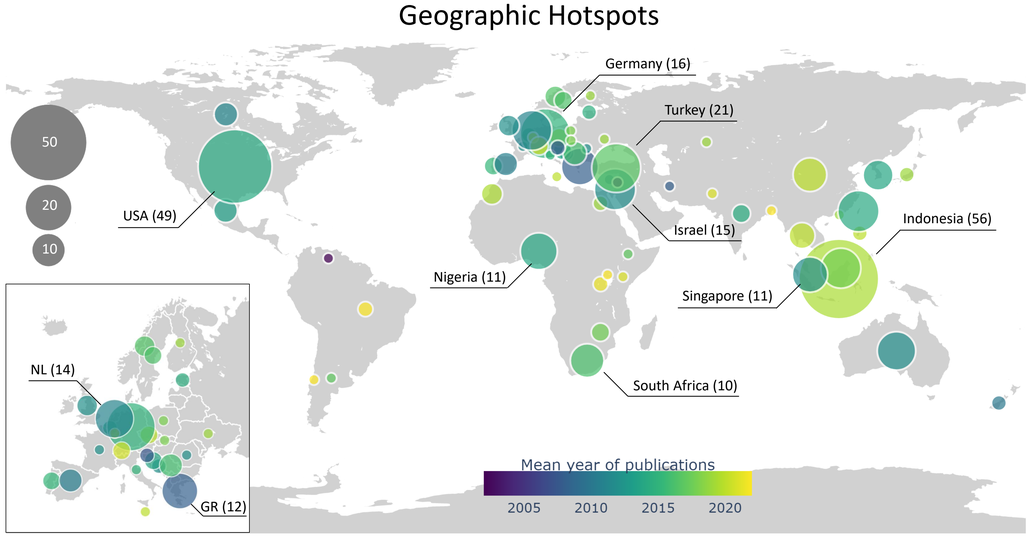
Development Over Time



Relative proportions of initial and final literature per year

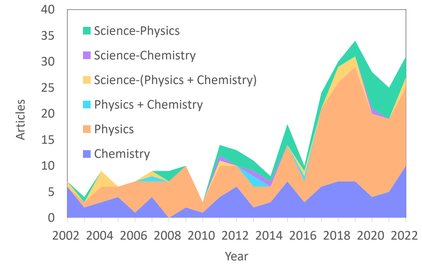
Problem solving is very active research field:
- Identified initial literature progresses similarly to general literature (Web of Science),
- Relevant PS literature (included literature) increases after 2016, but similar to the general educational literature,
- Research gap in 2010 (after first PISA studies).

Geographic Hotspots



Frequency of countries involved in the publications (counted by authors institutions) and mean year of these publications

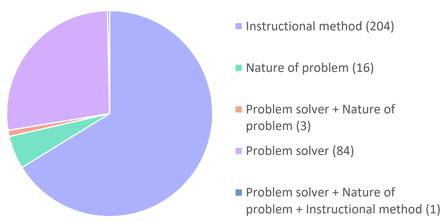
Domains



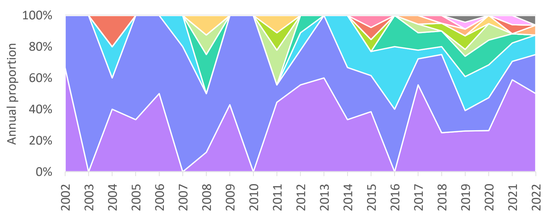
Share of domains in the final literature per year

- Strong geographic clustering (Europe, SEA, USA),
- Developing countries with many recent publications,
- **Indonesia effect**: 54 of 56 publications after 2016 by 170 different authors from more than 40 institutions,
- Domains disjunctively separated with physics-to-chemistry ratio of approx. 2:1 and few science studies
- Indonesia effect explains ratio (80% physics).

Types of Studies

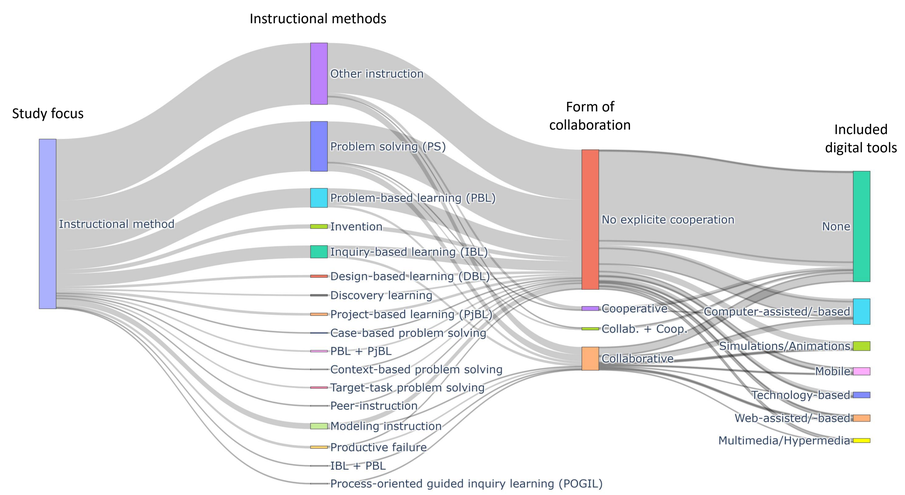


Main focus of studies and number of articles. "Nature of problem" includes different problem types and presentation forms, "Problem solver" mostly skill measurements.



Annual proportion of different instructional methods in the 204 studies. For color code see Sankey diagram (right).

Instructional Methods



Conclusion & Future Work

Results
- Very active research field with increasing number of publications,
- Currently strong influence of emerging countries,
- Clear Indonesia effect with >30% share of literature since 2017,
- Physics-to-chemistry ratio approx. 2:1 and disjunctive distribution,
- Very heterogeneous body of literature with different study focus,
- 66% of studies focus mainly on effects of instructional methods, 27% on problem solver metrics and just 7% on nature of problem,
- Problem-based learning and inquiry-based learning are the main tested instructional methods (besides general problem-solving instruction) with increase and further differentiation since 2013,
- Collaboration (13%) and digital tools (36%) are variously included.

Future Work
- Publication of the extensive data set including information about sample size, age groups and co-citation analysis,
- Sub-Analysis of thematically clustered literature,
- Meta-analysis of studies which focus on instructional methods.

Literatur

[†]Humboldt University of Berlin, Fachdidaktik und Lehr-/Lernforschung Chemie [*]Leibniz University Hannover, Institut für Didaktik der Mathematik und Physik

schmidt@idmp.uni-hannover.de