

Teaching Algorithm Design: A Systematic Literature Survey

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Introduction

Overview

In this poster, we present our first results from a **systematic survey of CS Education literature related to algorithm design education**. We provide a characterization of the literature, answering the following research questions:

- **RQ1: What algorithm topics are currently represented in the literature, and what kinds of studies are being conducted on these topics?**
- **RQ2: What kinds of interventions have been developed to teach algorithm design?**

Motivation

- **Algorithms are a critical part of an undergraduate CS degree and have clear practical applications.**
- Research on algorithm design instruction is **critically underrepresented in the literature.**
- A survey of the papers can **organize current knowledge, identify open questions, and guide future research.**

Methodology

Search Strategy

Our search was conducted on the ACM Full-Text Collection narrowed to **venues sponsored by SIGCSE, and ToCE**. We found that “Algorithms” was too broad of a search term to be feasible, so instead **we queried a list of Algorithms topics** based on prior work [1]. See central table for full list of topics. This returned 869 accessible papers. **Papers ranged from 1970 to July 2023.**

Study Selection

Papers were selected if they were both:

- relevant to **any of our topics or to an Algorithms course**,
- containing **data from college-level students**.

Only 96 papers met these criteria. In comparison, we counted 41 papers about CS0/1 in SIGCSE TS 2023 alone.

Paper Tagging

A **tagging scheme was developed inductively**, aiming to capture the following information about each paper:

- **Topic:** Does the paper focus on a specific topic? Which one(s)?
- **Evaluation:** How is data gathered, presented, and analyzed?
- **Metric:** What metric is measured by the data?
- **Intervention Target:** If the paper presents an intervention, what part of the course is targeted?

The first four authors tagged the papers independently after reaching sufficient inter-rater reliability.

Table 1: Tags by Topic. Note that some papers cover multiple topics, and contribute to each corresponding row in the table.

Topic	Total	Evaluation						Metric			Intervention							
		Quantitative Data	Survey	Scores/Grades	Statistical Tests	Controlled Trial	Qualitative Data	Interview	Thematic Coding	Performance	Affect	Persistence	None	Tools	Course Policy	Content Presentation	Discussion/Lab	Student Work
Branch-and-bound	1	1	0	1	0	0	1	0	1	1	0	0	1	0	0	0	0	0
Brute-force Algorithms	2	2	1	2	2	2	0	0	0	2	1	1	0	2	0	0	1	1
Depth- and Breadth-First Traversals	7	6	5	4	3	3	3	1	1	4	5	0	0	3	0	2	1	3
Divide-and-Conquer	3	3	1	3	2	1	2	1	0	3	0	0	2	1	0	0	1	0
Dynamic Programming	10	10	6	8	5	3	5	2	1	8	5	1	3	4	0	1	1	3
Greedy Algorithms	8	8	4	6	0	0	6	2	5	6	4	0	2	3	0	3	2	2
Heuristics	3	3	0	3	0	0	2	0	2	3	0	0	1	1	0	0	2	0
Minimum Spanning Trees	5	5	4	3	1	1	2	0	0	3	3	1	0	3	0	0	1	4
String/Text Algorithms	1	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1
Recursive Backtracking	3	3	2	3	1	1	2	0	1	3	2	0	1	2	0	1	1	0
Reductions	6	5	3	6	1	0	4	1	2	6	2	0	3	0	1	2	0	2
Representations of Graphs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shortest-path Algorithms	6	6	4	5	2	2	1	0	0	5	4	1	0	6	0	1	1	1
$O(n \log n)$ Sorting Algorithms	10	9	7	6	5	2	5	1	0	6	9	1	1	4	0	2	2	4
Total (at least one topic)	48	43	28	35	15	10	23	6	8	35	27	2	9	20	1	10	9	15
Not topic-specific	48	45	26	34	23	7	22	6	7	34	30	2	11	16	11	9	7	16
Total	96	88	54	69	38	17	45	12	15	69	57	4	20	36	12	19	16	31

The broad sparsity of papers indicates that many open questions remain about teaching algorithm design.

Major Takeaways

Topic-Specific Papers

- Most topic-specific papers focus on only one topic, but 14 were tagged with 2-4 topics.
- **Many topics are heavily under-studied.**
 - We found only three papers about Divide-and-Conquer. Of them, two focus on misconceptions.
- **The topics with more papers still have many open questions.**
 - Of the 8 papers on greedy algorithms, six are about interactive learning interventions, and none provide statistical tests or controlled trials, limiting our understanding of their effectiveness.

Papers Not Focused on a Specific Topic

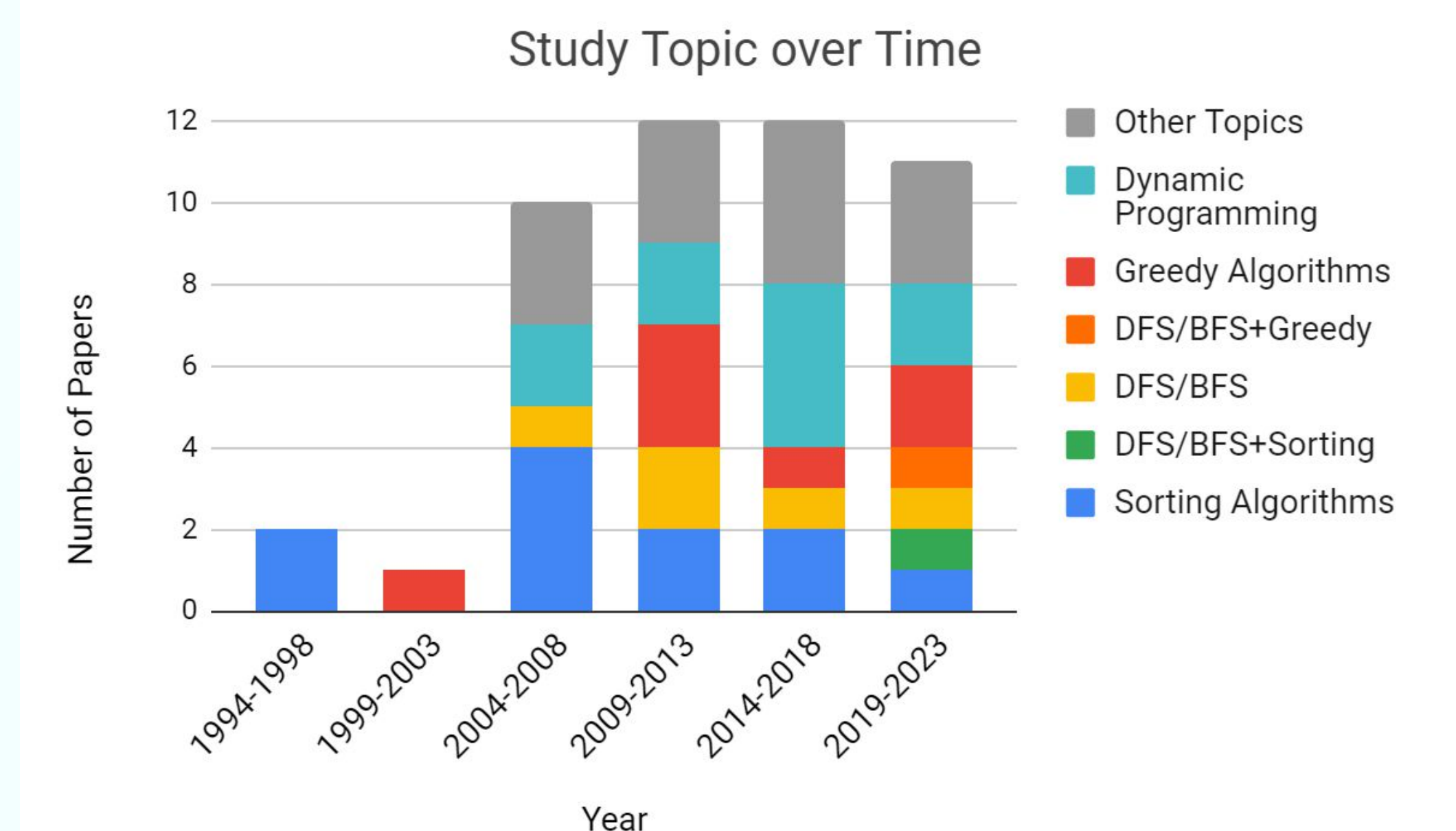
- **Most of these papers can be categorized as one of:**
 - **Course policy** interventions, especially assessment format and grading scheme,
 - **Think-alouds** about problem-solving strategies, or
 - **Tools** for facilitating algorithm visualization, classroom interaction, or automated assessment.
- Remarkably similar distribution of tags, with the major difference being a **larger emphasis on course policy**.

Other Findings

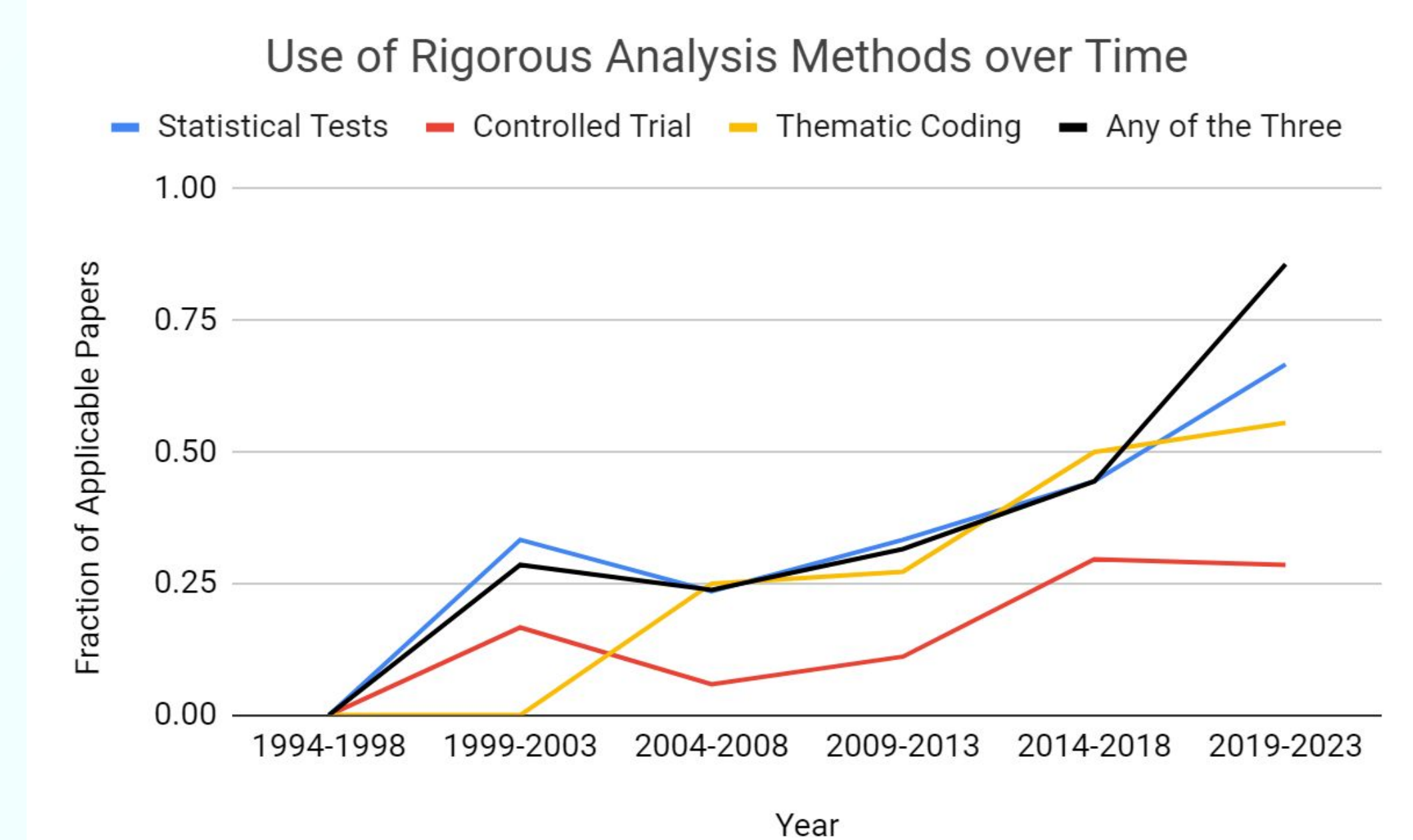
- **Few papers have been published about psychological factors** in Algorithms. (We found three.)
- There is also a **lack of papers on student experience and equitable pedagogy**.
- The papers are written by 208 unique authors. Of them, **191 authors only contribute to one paper, and 11 contribute to two**. We believe this indicates **limited depth of contribution**.

Trends over Time

Topics Covered



Scientific Rigor



Note that values listed here are as a fraction of the number of papers where the method is applicable to the type of data used. For example, “Thematic Coding” only considers papers presenting qualitative data.

Next Steps

We’re currently working on **consolidating findings from the papers into major themes**. For example, we’re finding that interesting problem selection can be motivational, whereas visualization tools are well-received but may not be helpful.

The List of Papers is Available!

If you’re interested in seeing the papers for yourself, the list (with tags) can be accessed at tinyurl.com/AlgsLitReview

If you have any questions or comments, please reach out to

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[1] Michael Luu et al. 2023. What is an Algorithms Course? Survey Results of Introductory Undergraduate Algorithms Courses in the U.S. SIGCSE 2023.