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What Are Cybersecurity Education Papers About?

A Systematic Literature Review of SIGCSE and ITiCSE Conferences

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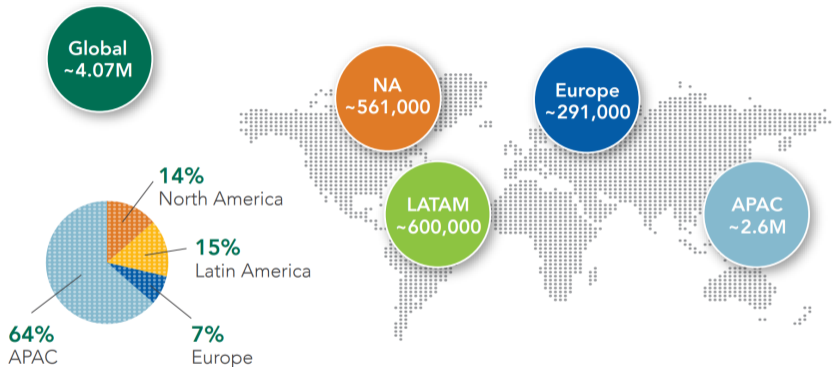
The Cybersecurity Workforce Gap Widens

Figure: Unfilled cybersecurity job positions globally[1]

[1]Source: https://www.isc2.org/Research/2019-Cybersecurity-Workforce-Study

Goal of the Paper

Understand the state of the art of cybersecurity education research and practice.

- Review the articles at SIGCSE and ITiCSE conferences
- Examine five research questions:

1. What **cybersecurity topics** are taught?
2. What is the **teaching context**?
3. How are the teaching interventions **evaluated**?
4. What is the **impact** of the published research?
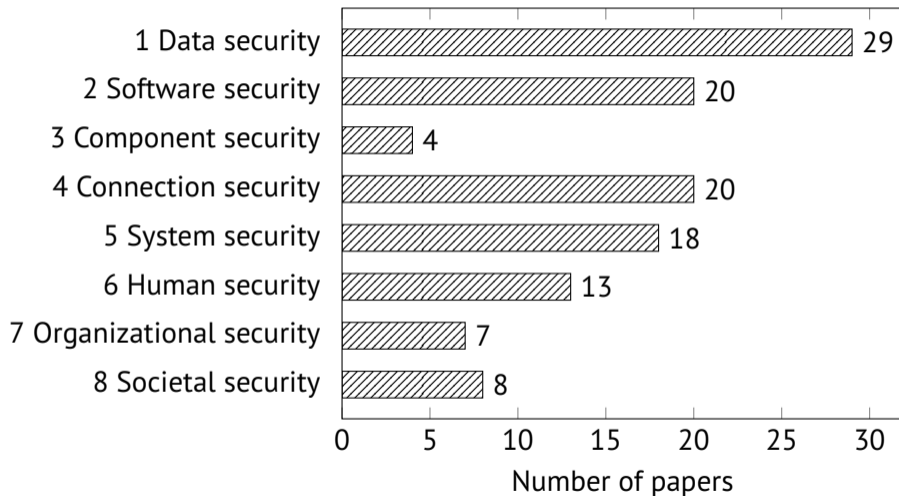5. Who are the members of the cybersecurity education **community**?

Method of Conducting the Literature Review

- Search query in the ACM Digital Library: `cybersecur* OR secur*`
- Constraints: **Since 2010**, filtered out 1- and 2-page long papers
  - SIGCSE: 68 papers (out of 1174 published)
  - ITiCSE: 22 papers (out of 574 published)
- Pilot reading by two authors eliminated 19 false positives
  - SIGCSE: 55 papers
  - ITiCSE: 16 papers
- Total: **71 papers** for review

Results for RQ1: What Topics Are Taught? (Open Coding)

- **Secure programming** and SW development, incl. reverse engineering (33%)
- **Network security** and monitoring (32%)
- **Offensive security**, cyber attacks, malware, hacking, and exploitation (24%)
- **Human aspects**, incl. privacy, social engineering, law, and ethics (24%)
- **Cryptography** (21%)
- **Authentication and authorization** (18%)

Results for RQ1: What Topics Are Taught? (JTF Curriculum Mapping)

Horizontal bar chart titled "Number of papers":

Topic	Number of papers
1 Data security	29
2 Software security	20
3 Component security	4
4 Connection security	20
5 System security	18
6 Human security	13
7 Organizational security	7
8 Societal security	8

Number of papers

Results for RQ2: How Are the Topics Taught?

- Target group: **Undergraduates** (76%)
  Also: instructors, K-12 students, professional learners
- Teaching method: **Hands-on learning, labs, exercises** (72%)
  Also: lectures, long-term projects, discussion, writing
- Time frame: **Semester-long course** (32%)
  Also: several hours, several days, several weeks

Results for RQ3: How Is Evaluation Performed?
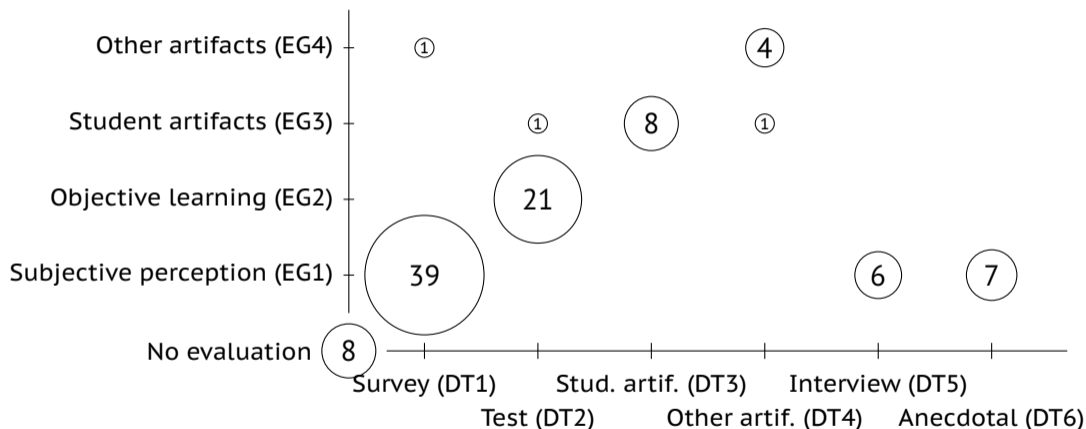
Results for RQ3: How Is Evaluation Performed?

- Evaluation methods: descriptive and inferential statistics, qualitative analysis
- Median sample size: **41 participants**
- The quality of reporting ranged widely
- No paper published the analyzed dataset

Results for RQ4: What Is the Impact of the Papers?

- 30 papers provided a link to supplementary materials (course materials, tools, …)
  - Only 22 of them are still available
  - This leaves **69% of papers without any materials**
- Citation count (unfair metric for recent papers):

	Min	Max	Median
Citations	0	18	2
Non-self citations	0	5	0

Results for RQ5: Who Forms the Cybersecurity Community?

- 251 author listings, **202 unique authors**
- **175 only one paper**, 14 two papers, 13 three or more papers
- Institutions: dominated by **universities and colleges** (88%)
  Also: military (9%), research institutes (3%)
- Countries: dominated by the **USA** (81%)
  Also: Canada (7%), Czech Republic (4%)

Summary of the Observed Trends

- **Topics**: secure programming, network security, cyber attacks, crypto, privacy
- **Format**: university course, hands-on exercise, teaching tool
- **Data**: from a few dozens of undergrads, collected throughout the semester
- **Evaluation**: questionnaires, pre- and post-tests, statistical analysis
- **Supplementary materials**: less than 1/3 of the papers, no datasets
- **Community**: North American universities, less than 1/7 of returning authors

Implications of this Literature Review

- **Open areas in research and practice**:
  - How to support teaching cybersecurity at the K-12 level?
  - How to motivate students to participate in cybersecurity education research?
  - How to employ educational data mining to analyze student data?
  - How do research trends in cybersecurity conferences overlap with cybersecurity education research conferences?

- **Steps to supporting high-quality research**:
  - Thorough reporting of research methods, incl. publishing of datasets
  - Clear description of learning outcomes mapped to a standardized curriculum
  - Sharing content (materials, tools, …) in stable public repositories

Thank you! Questions and feedback are welcome.

Read the full paper at `https://doi.org/10.1145/3328778.3366816`

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