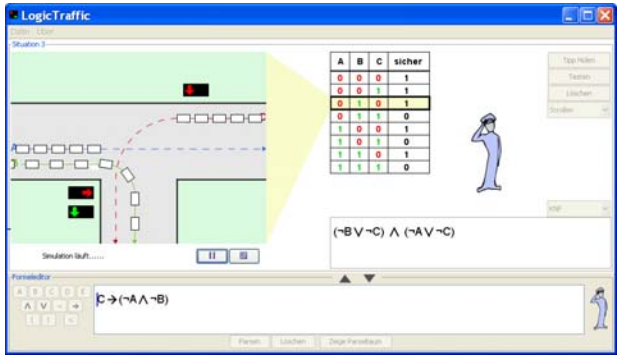
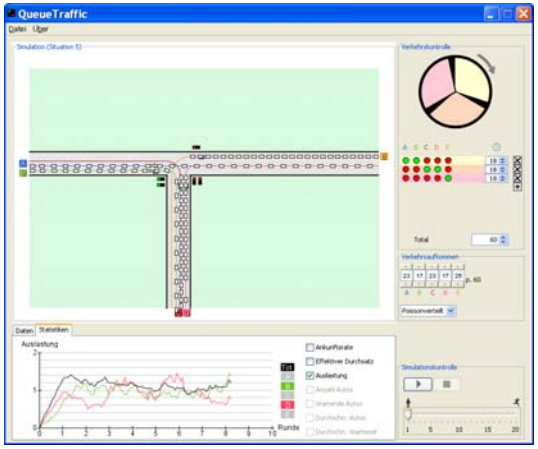
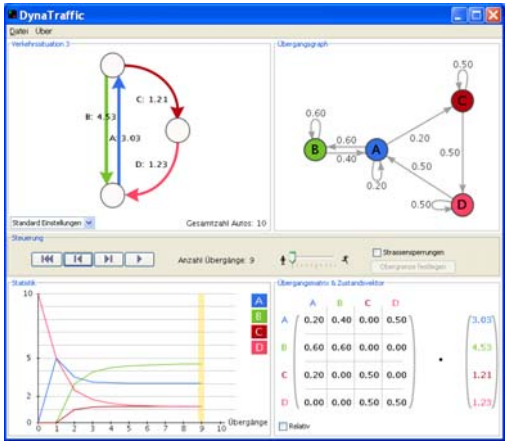
Interactive Learning Environments for Mathematical Topics

Doctoral examination

Ruedi Arnold

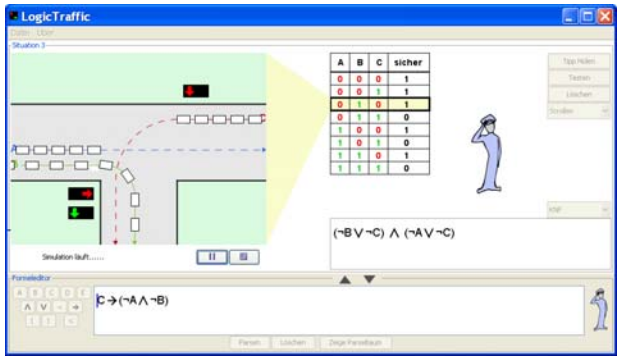




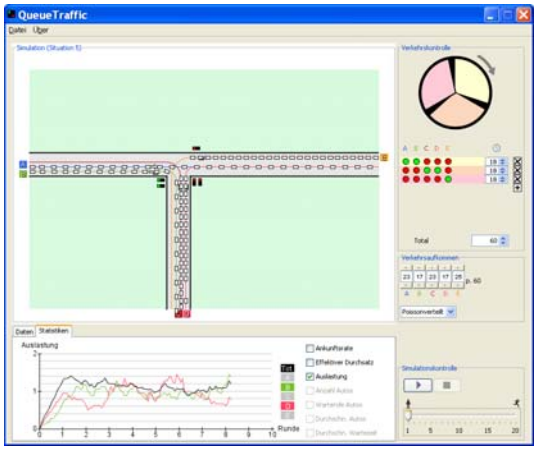


Interactive Learning Environments for Mathematical Topics

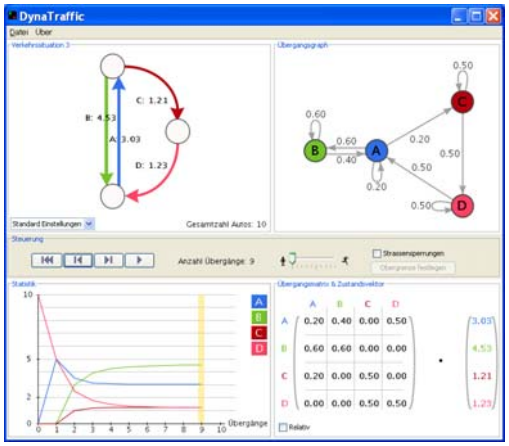
InfoTraffic is a collection of learning environments



LogicTraffic

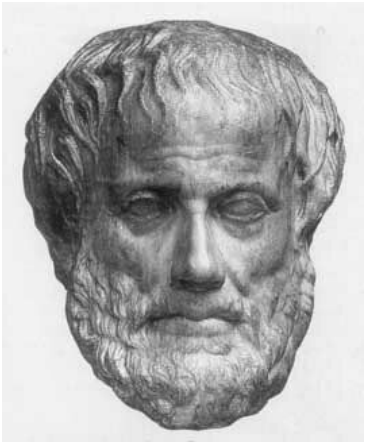


QueueTraffic



DynaTraffic

Motivation: Logic in General Education



Problem

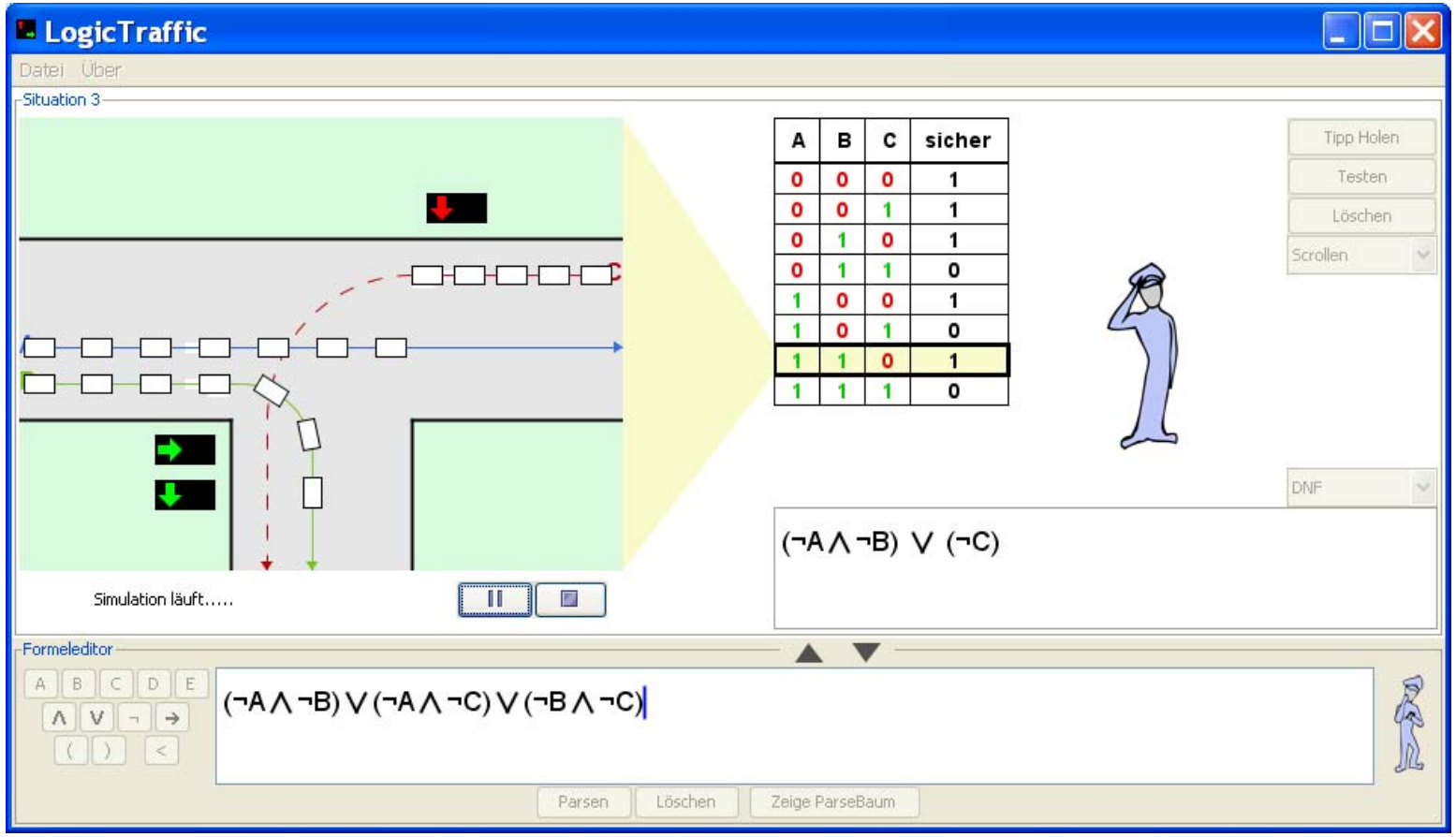
- Comprehension of logic is fundamental
- Today little significance in school practice

Analysis: Commonly taught in abstract manner and reduced to mathematical set of formulas

Modus Ponens
$((p \rightarrow q) \wedge p) \vdash q$

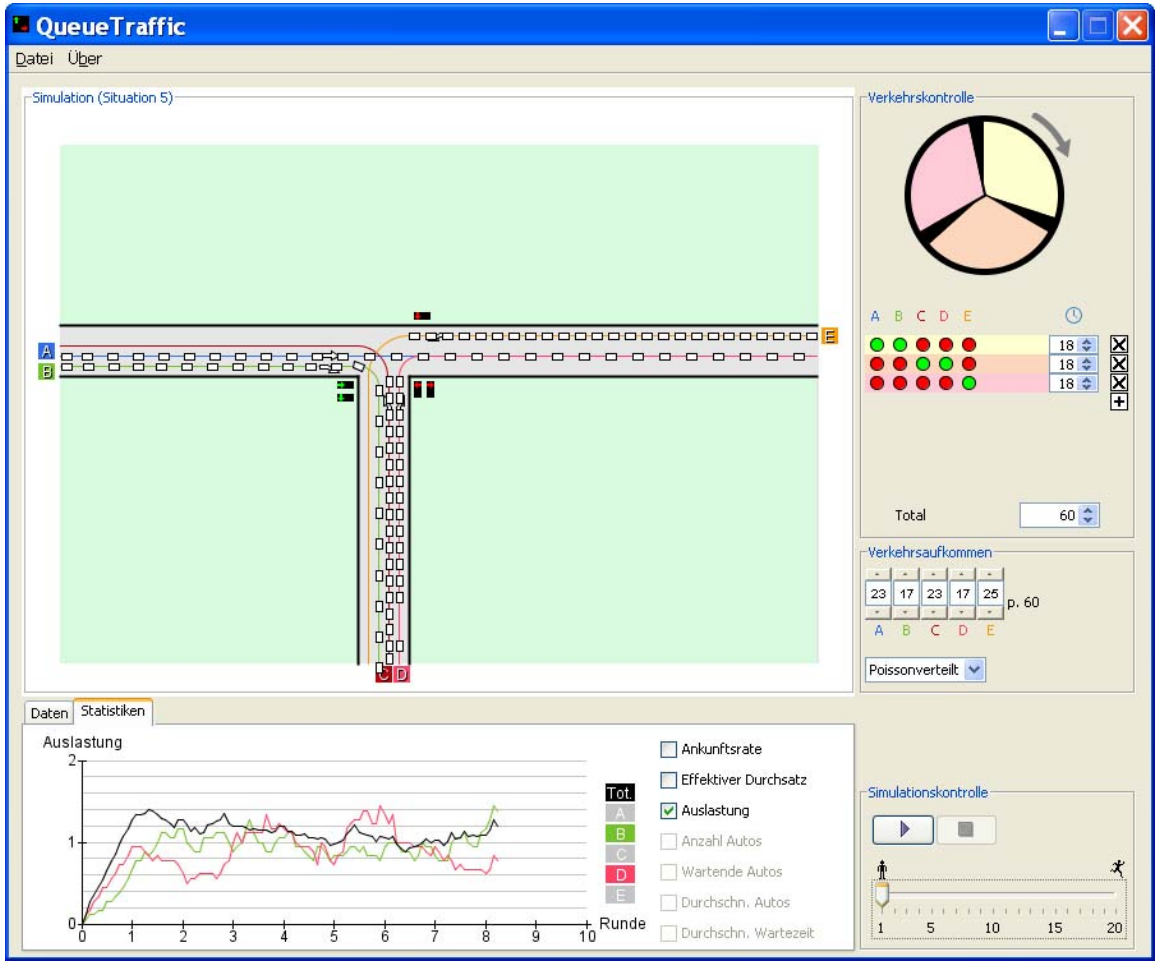
Solution: We offer a new approach to propositional logic based on real-world experience

LogicTraffic
Make Intersections Safe



Propositional logic: truth table, Boolean operators, equivalence of formulas...

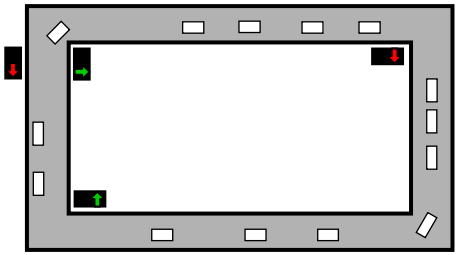
QueueTraffic
Control and Analysis of Intersections



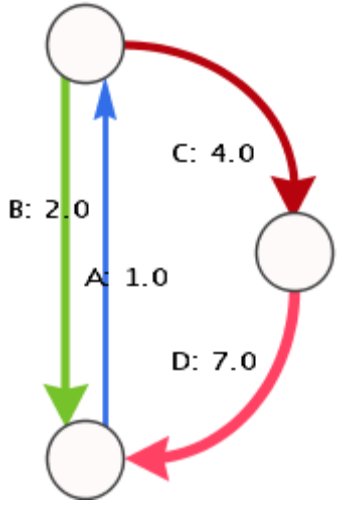
Queuing theory: throughput, utilization, Poisson distribution, arrival process, ...

DynaTraffic
Analysis and Prediction of Traffic Distribution

Everyday situation



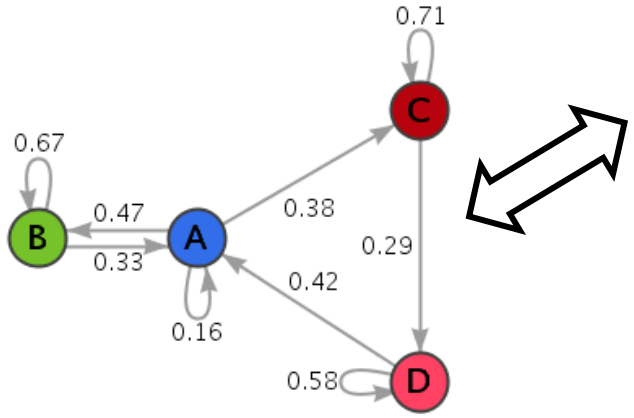
Simple model with cars



Abstract model without cars

	A	B	C	D
A	0.16	0.33	0.00	0.42
B	0.47	0.67	0.00	0.00
C	0.38	0.00	0.71	0.00
D	0.00	0.00	0.29	0.58

Transition matrix

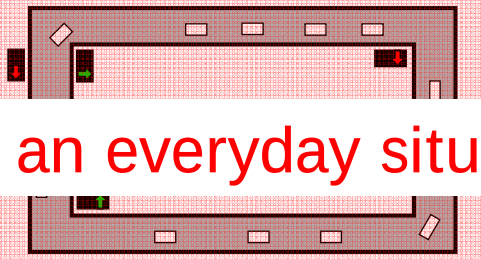


Transition graph

DynaTraffic

Analysis and Prediction of Traffic Distribution

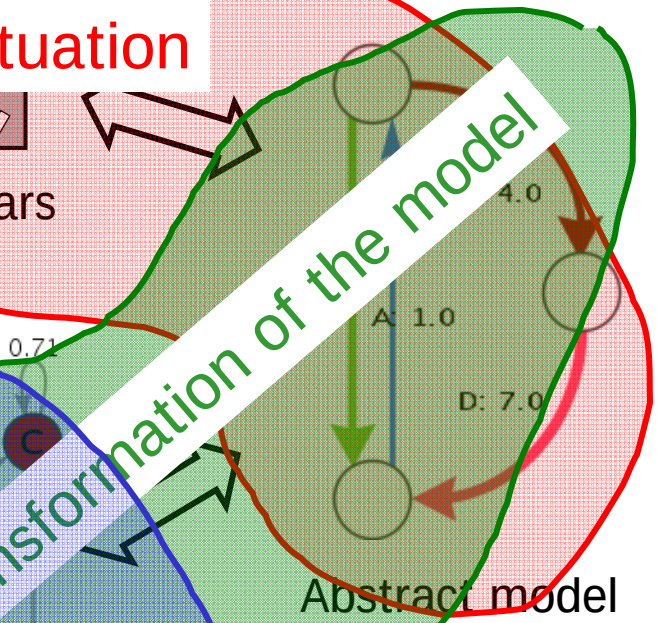
Everyday situation



Simple model with cars

Step 1: model of an everyday situation

Step 2: transformation of the model



Abstract model without cars

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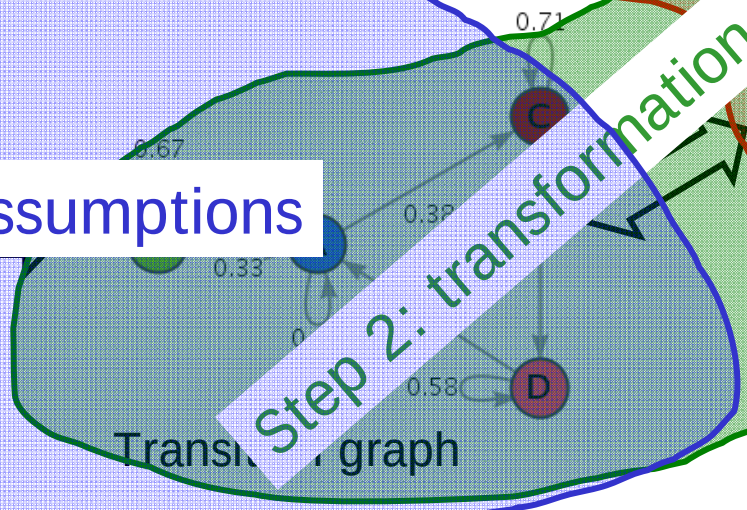
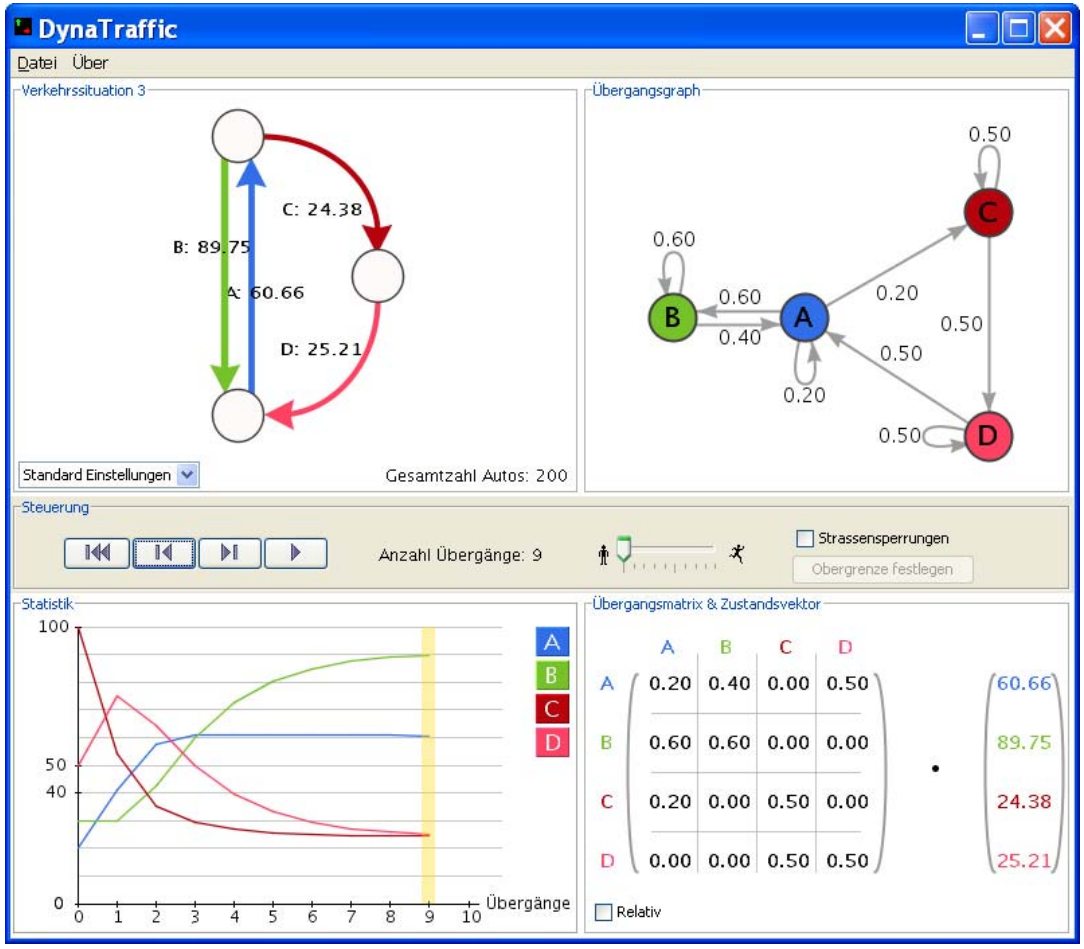
Transition matrix

Step 3: define assumptions



Transition graph

DynaTraffic



Markov Chains and Dynamic Systems: steady-state, transition matrix, periodic states, stochastic matrix, ...

InfoTraffic & Computers in Education

ICT as a Tool

- For everyday tasks (office, Internet, entertainment, ...)
- For specific tasks (accounting, math, publishing, ...)

ICT as a Medium

- Support teaching and learning
- Two main modes
  - Communication with other humans
  - Topic-specific educational software

ICT as a Subject

- Important concepts of computer science like programming, algorithms, propositional logic, queuing theory, or networks

InfoTraffic & Computers in Education

ICT as a Tool

- For everyday tasks (office, Internet, entertainment, ...)
- For specific tasks (accounting, math, publishing, ...)

ICT as a Medium

InfoTraffic:
Interactive Learning Environments (ILEs)
for important concepts from computer science and math

ICT as a Subject

- Important concepts of computer science like programming, algorithms, propositional logic, queuing theory, or networks

Didactical Concepts behind InfoTraffic
1. Content based on Fundamental Ideas

Propositional logic, queuing theory, and Markov chains are fundamental ideas according to Schwill [1]

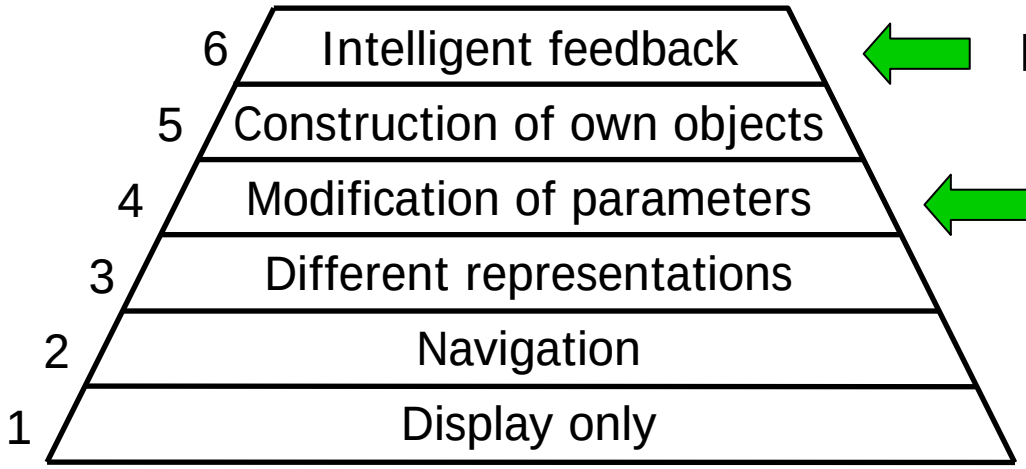
- Different applications
- On different cognitive levels
- Historically and in the longer perspective relevant
- Connection to everyday language and actions

⇨ **It's important and therefore worth the effort!**

[1] A. Schwill. Fundamental ideas of computer science. EATCS-Bulletin, 53:274-295, 1994.

Didactical Concepts behind InfoTraffic
2. High Level of Interactivity

Schulmeister [1]: 6 levels of interactivity



LogicTraffic

QueueTraffic,
DynaTraffic

Attractive for the „Nintendo Generation“ according to Guzdial and Soloway [2]
(animation, different possibilities for interaction)

[1] R. Schulmeister. Taxonomy of Multimedia Component Interactivity. A Contribution to the Current Metadata Debate. Studies in Communication Sciences. Studi di scienze della communicazione., 3(1):61-80, 2003.
[2] M. Guzdial and E. Soloway. Teaching the nintendo generation to program. Comm. of the ACM, 45(4):17-21, 2002.

Didactical Concepts behind InfoTraffic
3. Different Representations

Offering different representations: thinking can happen in three different media according to Bruner et. al [1]. Supplemented by a fourth representation by Hartmann et. al [2]

Symbolic - symbol

„tree“

Iconic - picture

Enactive - action

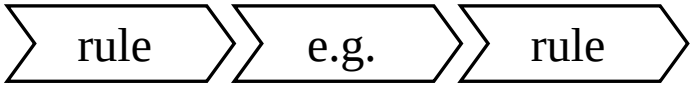
Virtual-enactive – simulated action

[1] J. S. Bruner, R. R. Oliver, and P. M. Greenfeld. Studies in Cognitive Growth. Wiley, New York, 1966.

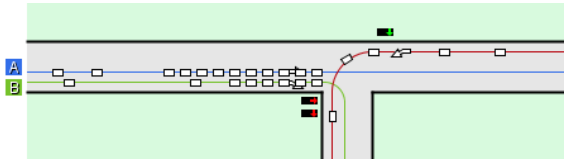
[2] W. Hartmann, M. Naef, and R. Reichert. Informatikunterricht planen und durchführen. Springer, Heidelberg Berlin New York, 2006.

Didactical Concepts behind InfoTraffic
4. Use of e.g.-rule-e.g.-rule Method

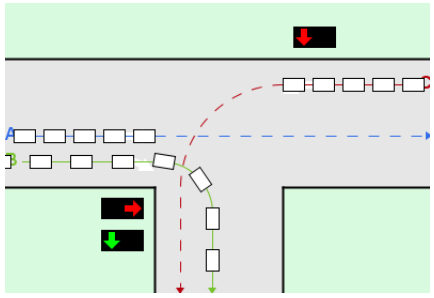
Teaching often based on the rule-e.g.-rule technique, according to Bligh [1]



1. For abstract content better use e.g.-rule-e.g.-rule:

Introduce Queues as M/M/1 system or as  ?

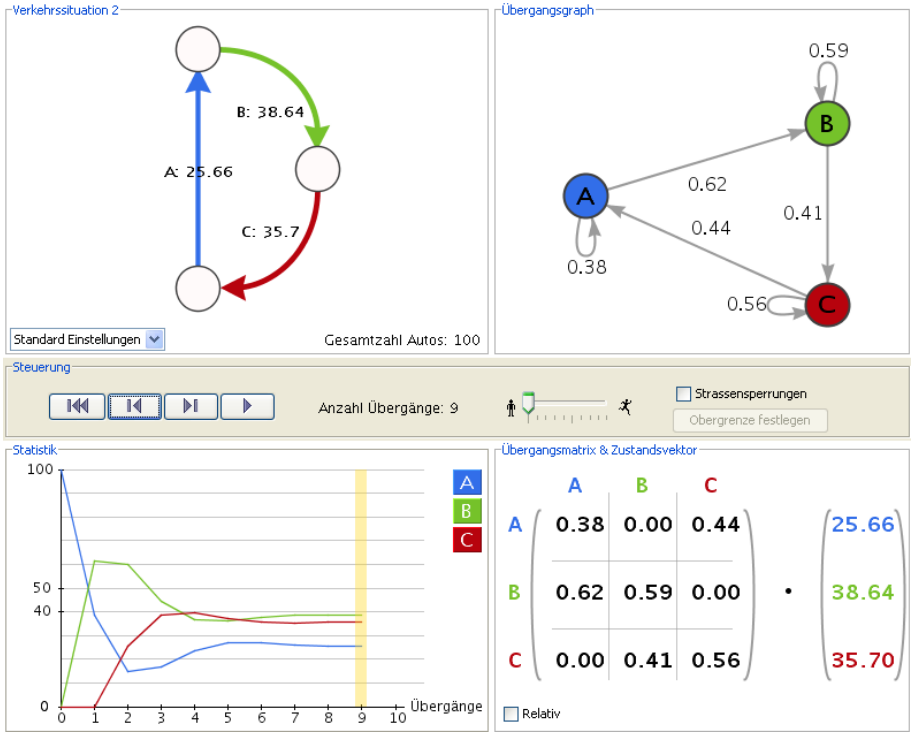
2. References to prior knowledge based on an **example from everyday life**



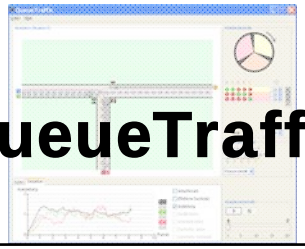
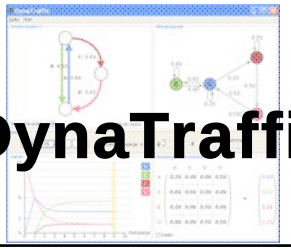
[1] D. A. Bligh. What is the Use of Lectures? Penguin Books, 1972.

Didactical Concepts behind InfoTraffic
5. Corresponding Views

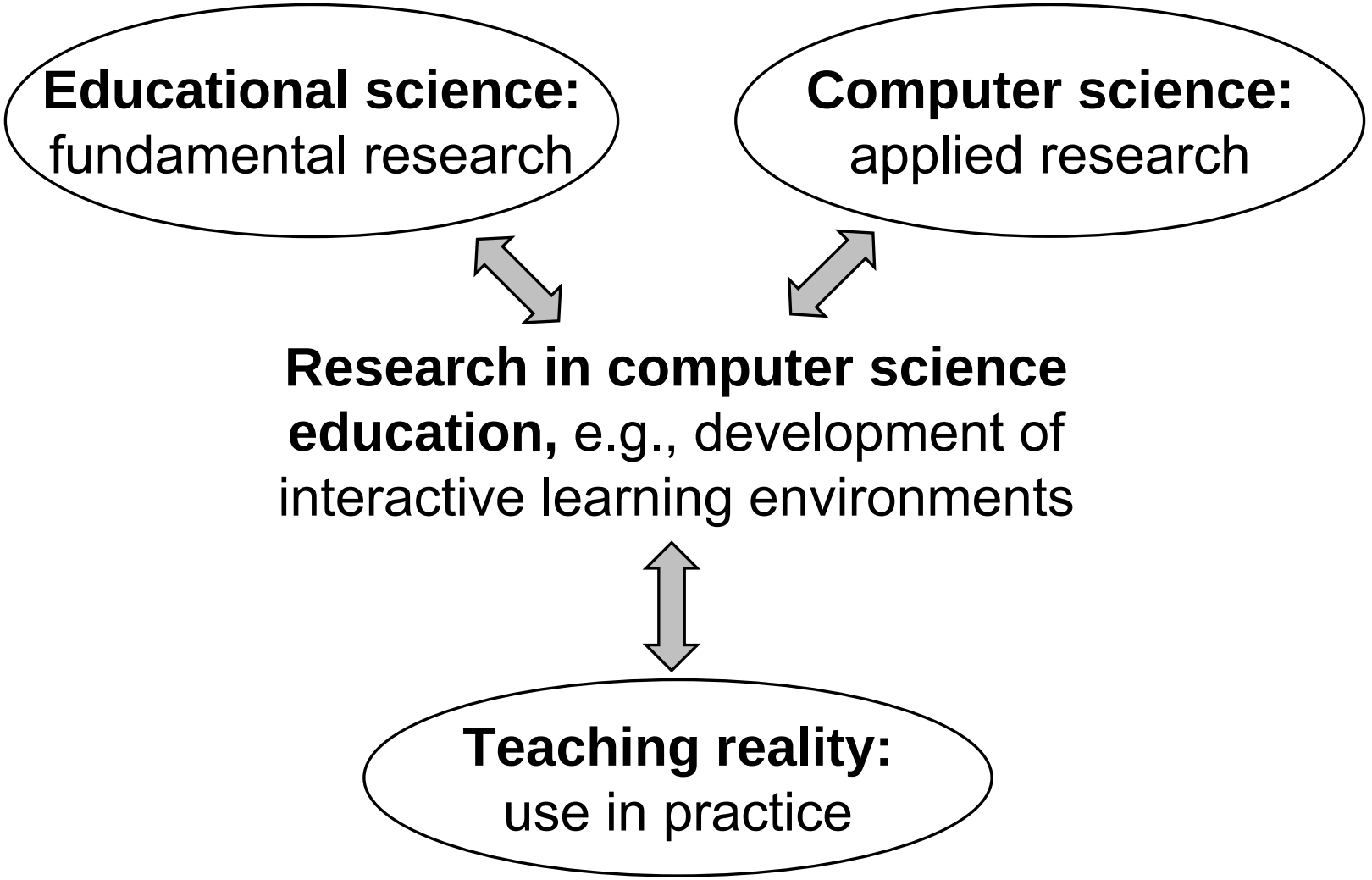
Multiple visualizations of the same content, automatically updated allows different approaches to the content, depending e.g. on the students' cognitive preferences and capabilities



Summary of Didactical Concepts behind InfoTraffic

Didactical Concept	 LogicTraffic	 QueueTraffic	 DynaTraffic
Fundamental Idea covered	☑	☑	☑
Level of Interactivity	6	4	4
Different Representations	☑	☑	☑
Begin with example from everyday life	☑	☑	☑
Corresponding Views	☑	☑	☑

Evaluation of InfoTraffic Interdisciplinary Research



Evaluation of ILEs from the Perspective of Educational Science

Classical scientific evaluation of effectiveness of learning environments is not appropriate [1,2]:

- "Complexity of real learning and teaching situations sets tight limits to experimental research. This leads to the case that most comparisons of teaching methods and teaching media show no significant results, and the few significant results contradict each other." [1]
- "Difficulties in generalizing statements from evaluations regularly tempt methodologists into calling for further differentiation and control in the methodical design. This leads to the construction of utterly artificial learning environments, whose evidence thus loses its validity for real life situations." [2]
- "...we do not need any of those 'careful studies of the impact of ... on ...'." [2]

[1] G. Reinmann. Nur "Forschung danach"? Vom faktischen und potentiellen Beitrag der Forschung zu alltagstauglichen Innovationen beim E-Learning. Arbeitsbericht Universität Augsburg, Nr. 14, 2006.
[2] R. Schulmeister. Grundlagen hypermedialer Lernsysteme: Theorie - Didaktik - Design, 4., überarbeitete und aktualisierte Auflage. Oldenbourg Wissenschaftsverlag, 2007.

The Approach of InfoTraffic

Current trend in educational sciences: focus more on design, development, and use [1,2,3]

Engineering Science Approach

- Pragmatically combine the best findings available
- Directly concerned with practical impact. “Understanding how the world works and helping it ’to work better’ by designing and systematically developing high-quality solutions to practical problems.” [2]

[1] Design-Based Research Collective. Design-Based Research: An Emerging Paradigm for Educational Inquiry. Educational Researcher, 32(1):5–8, 2003.
[2] H. Burkhardt and A. H. Schoenfeld. Improving Educational Research: Toward a More Useful, More Influential, and Better-Funded Enterprise. Educational Researcher, 32(9):3–14, 2003.
[3] F. Fischer, M. Waibel, and C. Wecker. Nutzenorientierte Forschung im Bildungsbereich: Argumente einer internationalen Diskussion. Zeitschrift für Erziehungswissenschaft, 8(3):427–442, 2005.

Impact of InfoTraffic on School Practice

Freely available online along with teaching material on a popular educational server

Used many times in high schools and teacher education courses

Impact of InfoTraffic
Anecdotal Evidence

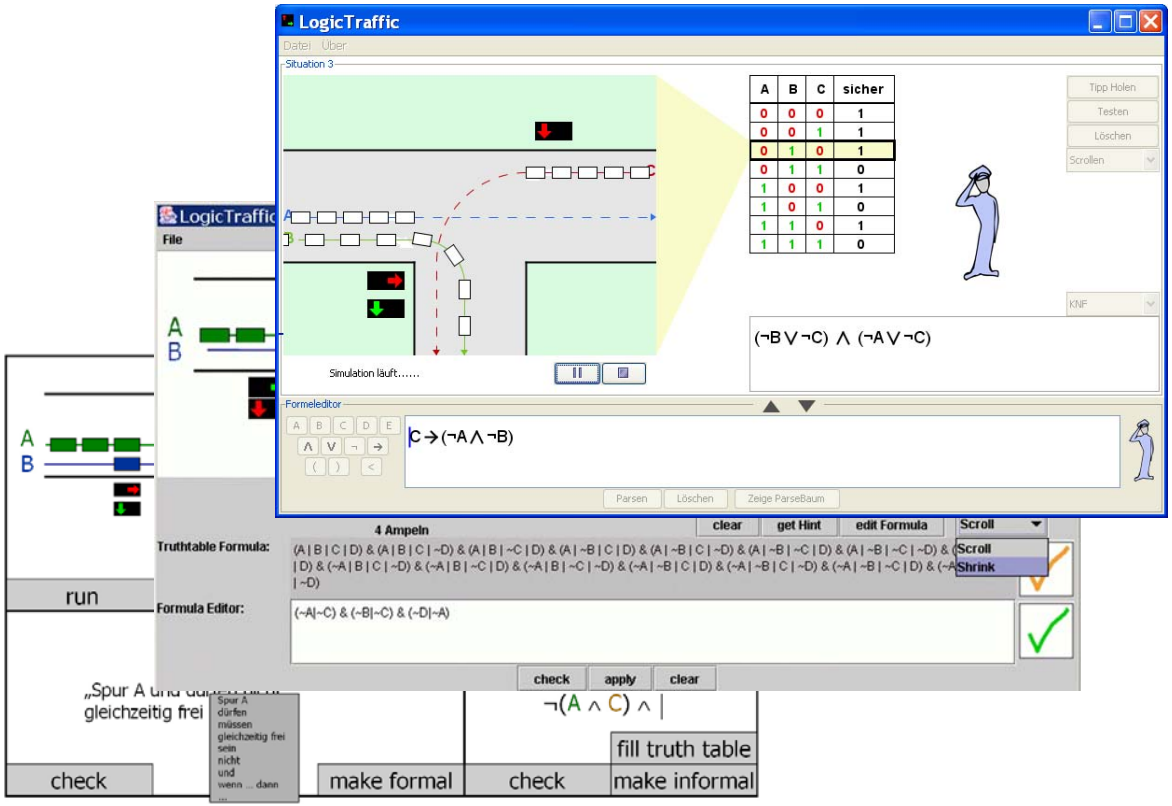
"Logik ist cool!" (Spontaneous statement of a high school student after having attended an introductory presentation to LogicTraffic)

"Poissonverteilung ist viel zufälliger, nicht wie bei einem Fliessband, wenn jede Sekunde ein Teil aus der Maschine kommt." (High school student after having solved exercises with QueueTraffic)

"Ich habe fast den gesamten Inhalt in meinen Informatikunterricht integriert, das heisst, ich habe die Schüler (13-19 Jahre) auf die Möglichkeiten/Grenzen von Simulationsprozessen hingewiesen und Ihre Simulationen testen lassen." (High school teacher after using QueueTraffic)

"I really believe that interactive learning with devices such as LogicTraffic is the best way for today's generation of students to learn." (American university professor using LogicTraffic in his classes)

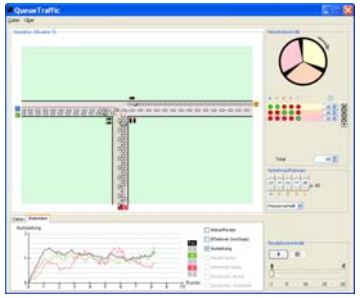
Pragmatic Recommendations for Development of ILEs [1]

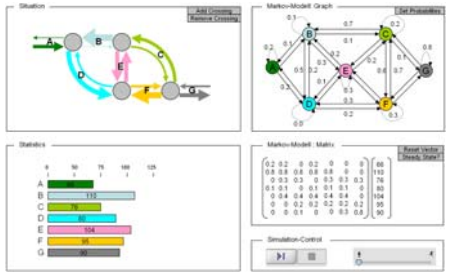


[1] R. Arnold und W. Hartmann. Pragmatische Empfehlungen zur Entwicklung von interaktiven Lernumgebungen. INFOS 2007, 12. GI-Fachtagung Informatik und Schule, Siegen. GI-Lectures Notes in Informatics, pp. 171-182, September 2007.

Contributions of this thesis

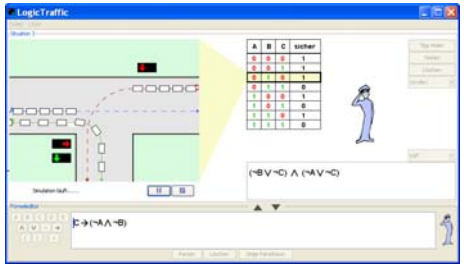
A real-world-based approach to propositional logic, queuing theory, and Markov chains





Guidelines for pragmatic and interdisciplinary engineering of ILEs

A virtual-enactive introduction to topics from math and computer science



“Logik ist cool!”

Increasing the significance of logic in general education

The End - Thank you

Relevant publications

R. Arnold and W. Hartmann. **Pragmatische Empfehlungen zur Entwicklung von interaktiven Lernumgebungen**. In Proceedings INFOS 2007, 12. GI-Fachtagung Informatik und Schule, Siegen, Germany, September 2007.

R. Arnold. Demonstration abstract: **Introducing Propositional Logic and Queueing Theory with the InfoTraffic Interactive Learning Environments**. In Proceedings of ACM ITiCSE 2007, Dundee, Scotland, June 2007.

R. Arnold, M. Langheinrich, and W. Hartmann. **InfoTraffic - Teaching Important Concepts of Computer Science and Math through Real-World Examples**. In Proceedings ACM SIGCSE Technical Symposium, pages 105–109, Covington, Kentucky, USA, March 2007.

R. Arnold and W. Hartmann. **LogicTraffic – Logik in der Allgemeinbildung**. Hauptbeitrag Informatik-Spektrum, 30(1):19–26, 2, 2007.

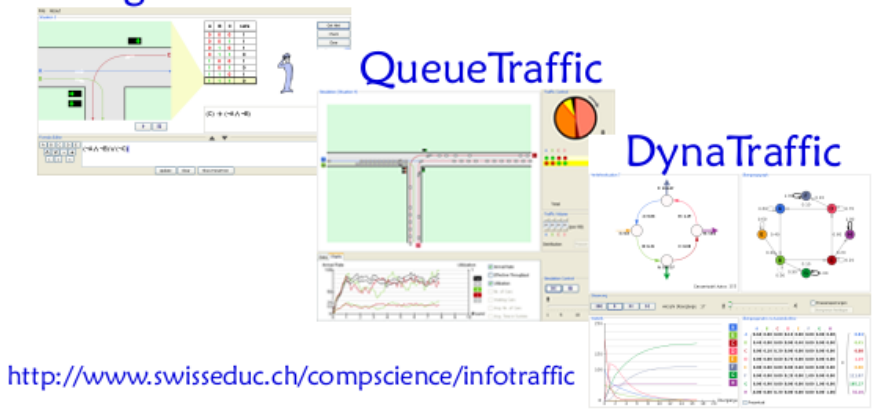
Acknowledgements

InfoTraffic

LogicTraffic

QueueTraffic

DynaTraffic



http://www.swisseduc.ch/compscience/infotraffic

Idea & Concept:
Ruedi Arnold,
Werner Hartmann

Realization:
Ruedi Arnold, Nicolas Born, Marc Bühler,
Hasan Karahan, Anna-Nina Simonetto,
Lea Simonetto, Xiaoping Yin