Braided Teaching in Secondary CS Education: Contexts, Continuity, and the Role of Programming

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1. Introduction
2. Theoretical Framework and Related Work
3. Practical Background and Implications
4. Conclusions

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Role of Computer Science in (Lower) Secondary Education:

- Diminishing (or non-existing) curriculum credit for CS.
- “Information and Communication Technology vs. CS” debate.
- Slight variations across states and countries, yet same general theme.

Breadth of Computer Science as a Subject:

- Ranging from (Electrical) Engineering to (Discrete) Mathematics.
  - Can reach out to students with varying aptitudes and interests.
  - Wealth of subject matters and application contexts.
- One of the distinguishing features (not only in secondary education).

Alas, hard (if not impossible) to teach along a spiral curriculum.

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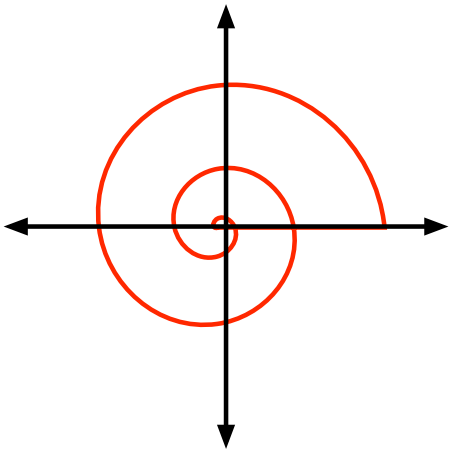
Spiral Curriculum [Bruner, 1960]:

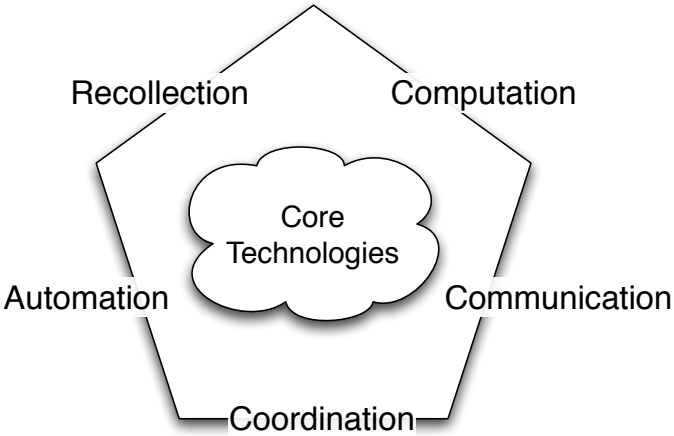
- "Any subject can be taught effectively in some intellectually honest form to any child at any stage of development."
- Multiple iterations needed to reach an understanding at adult level.
- Obvious "depth-versus-breadth" problem...



Computing Mechanics [Denning, 2003]:

- Structure and operation of computations.
- Windows to look at core technologies:

  "Although the views through the edges of windows overlap, the view through the centers is distinctive."



Observations:

- Majority of courses in secondary education focus on programming.
- Tremendous progress with (meta-)microworlds for outreach/teaching.
  - Alice, Greenfoot, Scratch, [insert your favorite here] (to name a few).
- Community (still) struggling with "OO first/late/never".

Recent Debate in CACM on the "CS = Programming" Portrait.

What the ACM K-12 Model Curriculum says:

> "While programming is a central activity in computer science, it is only a tool that provides a window into a much richer academic and professional field." [Tucker *et al.*, 2004, p. 6]

Observations:

- Multiple responses to diminishing interest in/credit for CS in secondary education.
- Breadth of the subject matter versus spiral curriculum.
- Multiple viewpoints w.r.t. the role of programming.

Objectives:

- Propose a new way of thinking about implementing CS curricula…
- …that leaves as much leeway to educators as possible
- …and that is compatible with established procedures.
- Finally: give evidence for why it should be more than just “Philosophy”.

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Definition 2.1

A strand is a sequence of items addressed in class that satisfies the following criteria:

1. The items can be assigned to a well-defined subject matter (by their structure or their content). → Coherency
2. The subject matter is identifiable and recognizable to the students throughout the sequence. → Transparency
3. The subject matter is being presented from more than one point of view or embedded in more than one context. → Variance
4. The sequence of items is addressed in more than one teaching unit. → Redundancy

Note: A strand does not require a particular order to be imposed on its items.

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Objective and Subjective Criteria:

1. "The items can be assigned to a well-defined subject matter."
   - Purely objective criterion; can be verified easily.
2. "[...] identifiable/recognizable to the students throughout sequence."
3. "[...] presented from more than one point of view [...]."
4. "[...] addressed in more than one teaching unit. [...]"
   - In the responsibility of the educator; situated. Cf. this SIGCSE's keynotes.
   - Subject to structural and pedagogical considerations by the educator.
   - Subject to external factors such as curriculum or "teaching tradition".

Implications:

- (3) → Aptitudes/interests, cf. "windows of computing mechanics".
- (4) → Spiral curriculum, cf. this morning's keynote ("spaced in time").

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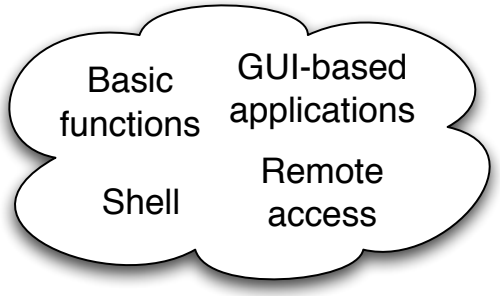
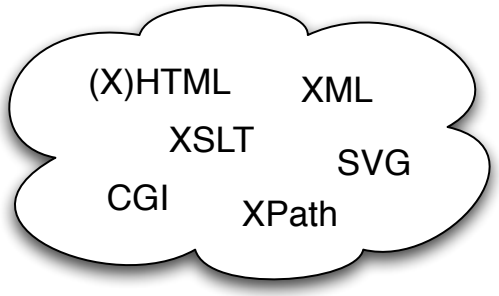
Operating Systems



Stand organized by content.

(Semi-)Structured Data



Strand organized by structure.

A strand is different from the following:

- …"Fundamental idea" [Schwill, 1997]
  - Mastery allows for transfer of principles ("(Semi-)Structured Data").
  - Organization exclusively from the perspective of the educator.
- …"Threads™" [Furst *et al.*, 2007]
  - Collection of sequences of courses to fulfill college(!) curriculum.
  - Organization by the educators, selection by the students.

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Why Contextualized Teaching?

- Increased motivation & effectiveness [Tew *et al.*, 2008].

"On the Nature of 'Context' in Chemistry Education" [Gilbert, 2006]:

- There is no single notion of "context".
- Higher secondary education and college:
  - "Reciprocity between concepts and applications." (MediaComputation)
- Lower secondary education:
  - "Topics and [...] activities [...] [important] to [...] the society."

Contexts Compared to Strands:

- Coherent time frame for presenting items from (more than) one strand.

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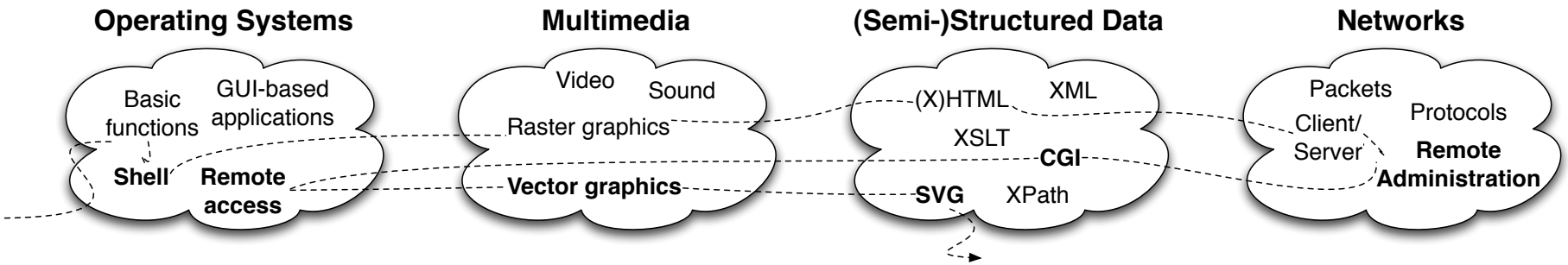
Definition 2.2

Braided teaching is the process of covering the contents of a given curriculum by a collections of strands that are interlaced wherever appropriate.



Observation:

- By definition (of a strand): no single "programming" unit allowed.

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Observation:

- Programming ≈ using the computer to solve otherwise seemingly infeasible problems.

In the Good Old Days™:

- In-depth treatment of a small number of topics possible.
- Few (if any) software available in the public domain.

Today:

- Increasingly complex contexts covered breadth-~~first~~ only.
- Much free and possibly open source software available; can download a program for seemingly any problem touched upon in high school.

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Considering “Programming” as a Strand:

- Admittedly, not every concept can be taught from multiple viewpoints.
- Attributes the role delineated in the ACM K-12 Curriculum.

> “While programming is a central activity in computer science, it is only a tool that provides a window into a much richer academic and professional field.” [Tucker *et al.*, 2004, p. 6]

- “One among many”-status prohibits “CS = Programming” image.
- Ultimately, allows an educator to choose a programming language based upon its usability for a particular course design.

> **Disclaimer:** This may or may not be possible in a particular country / state / school district and/or lead to more philosophical discussions…but where to present such considerations if not in a “Philosophy” session?

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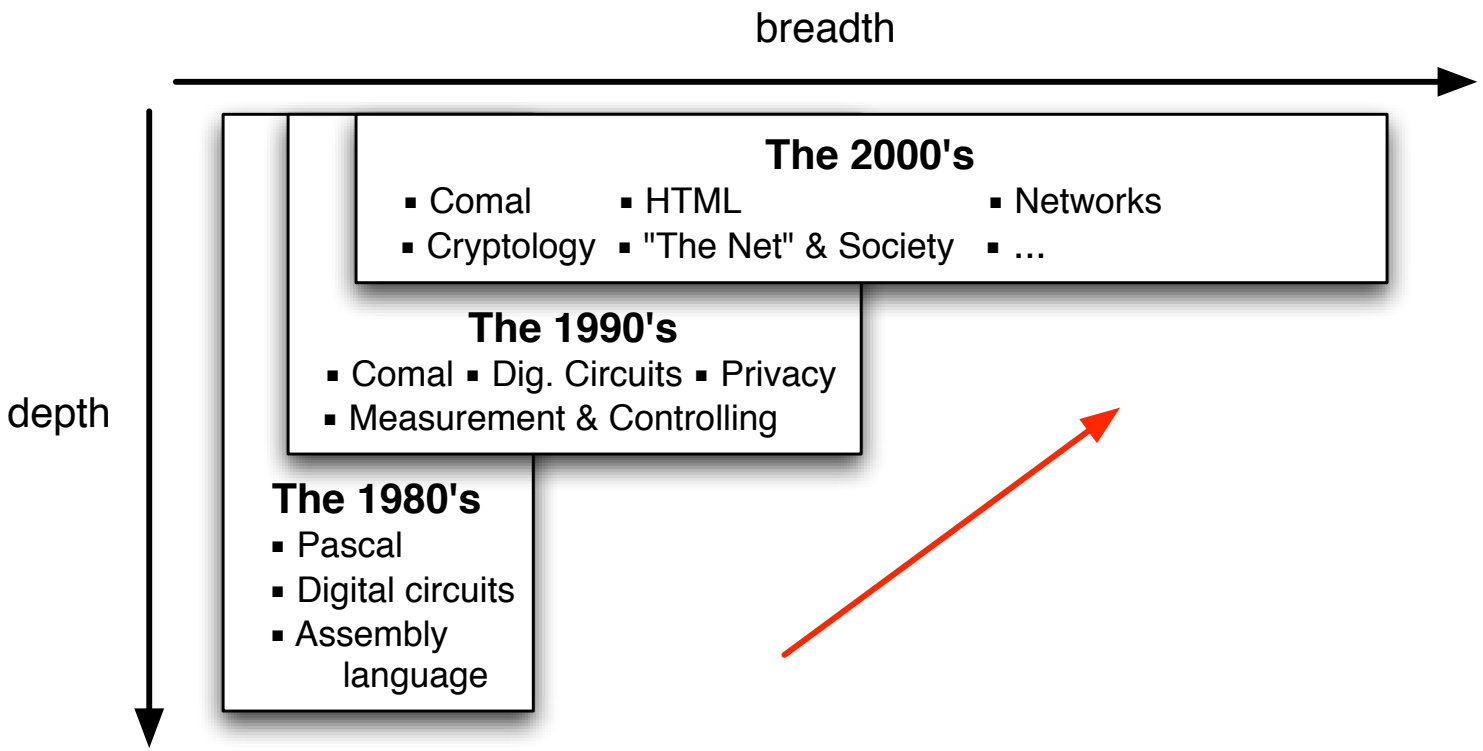
Bio in a Nutshell:

- Teaching qualification for Computer Science, Physics, and Mathematics.
- Almost 30 years of teaching experience on secondary level.
- Joined part-time PhD program at TU Dortmund in 2008.

Fritz-Steinhoff-Gesamtschule Hagen:

- Secondary school (grades 5-13) with 1,500 students.
- CS has been taught at FSG Hagen since (at least) 1983.
  - Unfortunately, CS is neither mandatory not (in general) worth full credit.
  - Fortunately, the latter is going to change at FSG `:-)`.



Observations:

- Breadth of topics increased; course volume did not.
- Common component: Programming.

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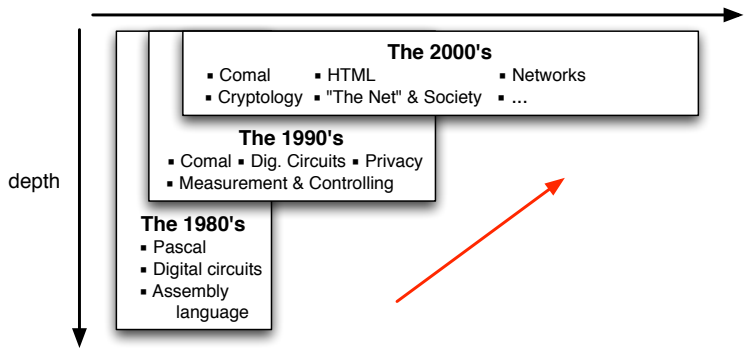
Observation:

- Programming ≈ using the computer to solve otherwise seemingly infeasible problems.



Today's Classroom Situation:

- Increasingly complex contexts covered breadth-~~first~~ only.
- In lower and middle secondary education:
  - Students very well aware of "Computers and the internet".
  - Programming (in the above sense) increasingly difficult.
  - Still possible: Working with "elementary" tasks and tools.
- Need to relate subject matters to (the students') everyday life.
- Present meaningful, yet feasible programming tasks.
  - Remember: Programming is a tool, not a goal in itself.

Example: Contexts for Programming Tasks

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Context	Subject Matter	Strand
Produce flip book animations	Scripting & animated GIFs	Multimedia
Create web page for field trip	XHTML	(Semi-)Structured Data
Maintain a database for an MP3 collection	XML data base	(Semi-)Structured Data
Create guest book for school's web server	CGI scripting	(Semi-)Structured Data / Networks
Discuss security of online shopping	Cryptology	Networks
Remotely maintain a client or server	Shell scripting	Operating Systems / Networks

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Pedagogical Imperative: "Programming as a Tool"

- Learning a particular language is not a first-order objective.
- Choose subject matters first, then a fitting language.
- In our situation: Contexts at times interactive and/or graphical.

One Possible Language of Choice: Tcl/Tk(⋆) [Ousterhout, 1994]

- Highly interactive language; integrates with OS's shell.
  - For favorable evaulations of scripting in introductory CS courses, see, e.g., [Clements & Meredith, 1993, Warren, 2001, Graham & Latulipe, 2003].
- Allows for realization of CGI scripts and (Java-)applet-like scripts.
- Allows for (does not enforce) object-orientation via graphics toolkit Tk.

(⋆): Based on your experiences, you may prefer X over Tcl/Tk. This is perfectly fine!

From Theory to Practice:

- New course “Computer Science and Physics”.
  - Target group: Grades 6 to 10; 3 hours/week.
  - Elective course, yet worth full curriculum credit.
  - Start: Summer 2010.
- Course designed according to the “braided teaching” philosophy.
- Touching points with contexts from Physics.

Project Evaluation:

- Evaluation done by fellow PhD student (I’m teaching, after all).
- Control group design possible (→ *elective* course).

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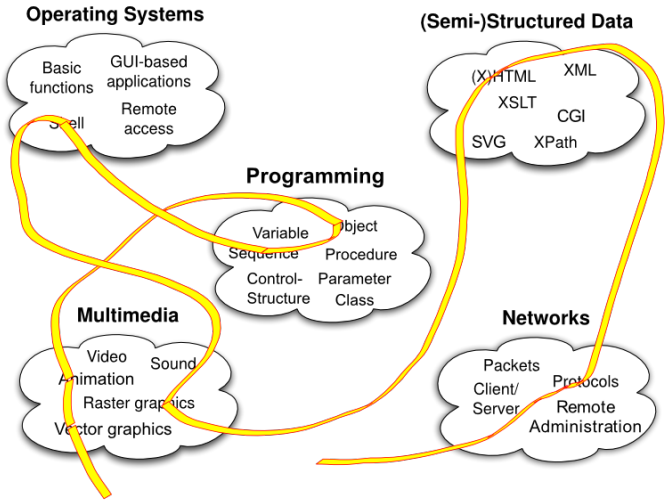
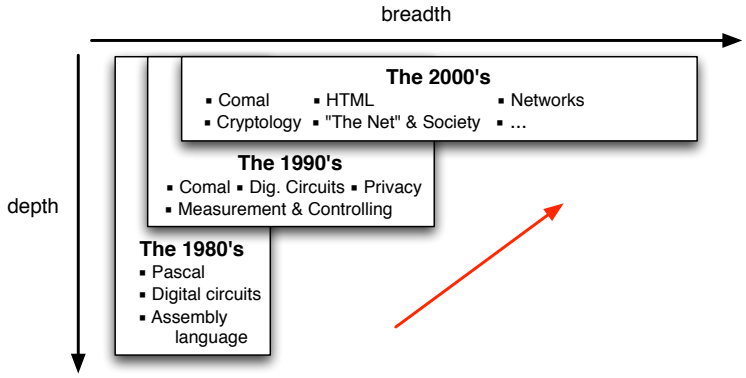
Braided Teaching:

- Organization along strands.
  - Coherency, transparency, variance, redundancy.
- Programming as a tool → strand.
- Potential:
  - Teaching along a spiral curriculum.
  - More leeway for educators' decisions.





Future Work:

- Transform philosophy into practice and non-useless truth.
- Investigate extension to higher secondary and college education.

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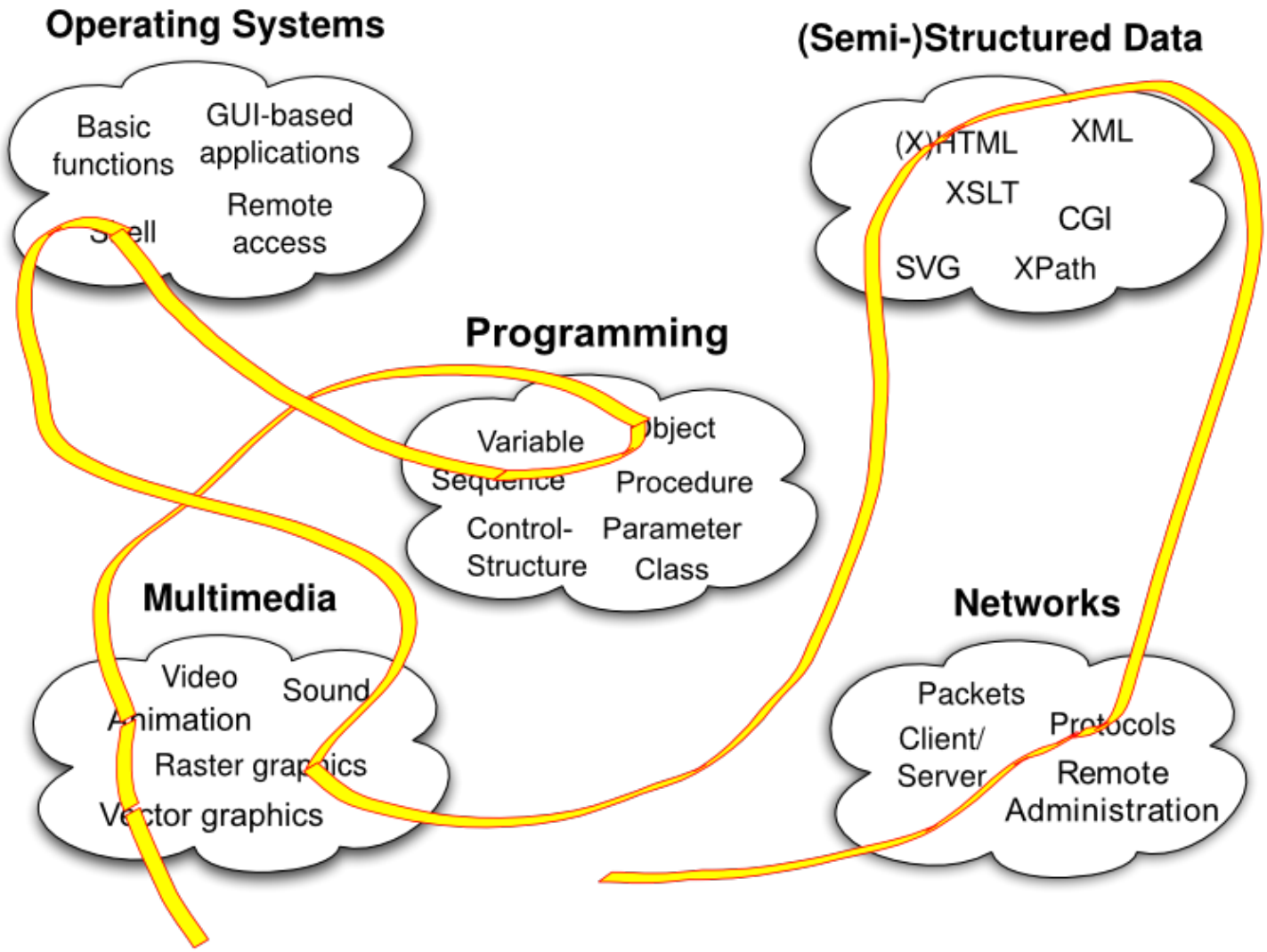
Course for Grades 9 and 10:

- Strands interlaced throughout the course:
  - Operating Systems, Multimedia, (Semi-)Structured Data, Networks.

Sequence in a Nutshell:

- Using shell commands for working with files and directories.
- Exemplary installation of a small software package.
- Automating tasks by using shell scripts.
- (X)HTML for describing web pages and representing structured data.
- Uploading and maintaining pages on a web server.
- Using CGI for automated document creation.
- Representing and creating animated graphics with SVG.


Operating Systems
Basic functions
GUI-based applications
Remote access
(Semi-)Structured Data
(X)HTML
XML
XSLT
CGI
SVG
XPath
Programming
Variable
Procedure
Control-Structure
Parameter
Class
Multimedia
Video
Sound
Animation
Raster graphics
Vector graphics
Networks
Packets
Client/Server
Protocols
Remote Administration

Situation in Germany:

- Pretty much the same as everywhere:
  - CS education in each state's responsibility.
  - Diminishing curriculum credit, only few fully qualified teachers per school.
- But there is a twist: "Educational Standards for Computer Science in Lower Secondary Education" (see, e.g. [Brinda *et al.*, 2009]).
  - Outcome-based standards, modeled after NCTM's standards for Mathematics.
  - Result of a multi-year effort of 70+ educators and researchers.
  - Standards (not curricula nor their implementation) defined first!
  - Assumption: CS taught at least one session per week starting in fifth grade.
- Opportunity: rethink what and how to teach in secondary CS courses.