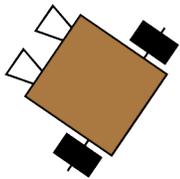


tales of educational robotics: *teaching, research and outreach with RoboCupJunior*

Elizabeth Sklar
Agents Lab

Dept of Computer and Information Science
Brooklyn College, City University of New York
sklar@sci.brooklyn.cuny.edu



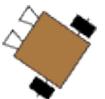
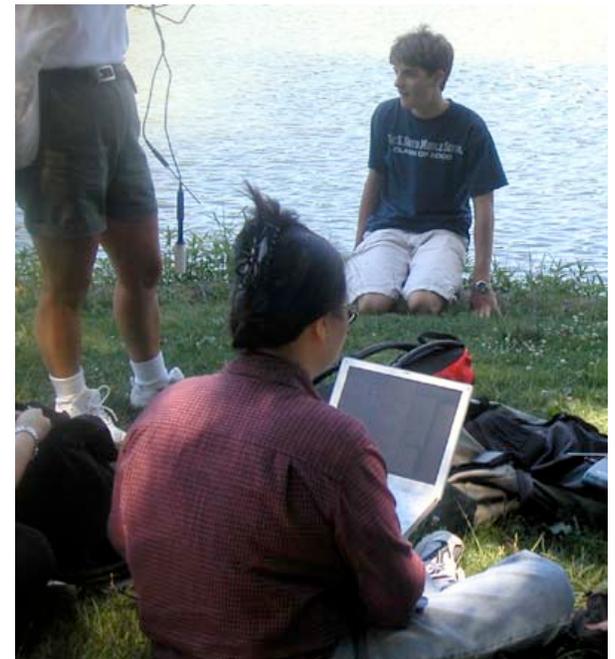
robotics as a multimedia learning environment

- traditional learning environments are text dominated
- but today, multimedia pervades

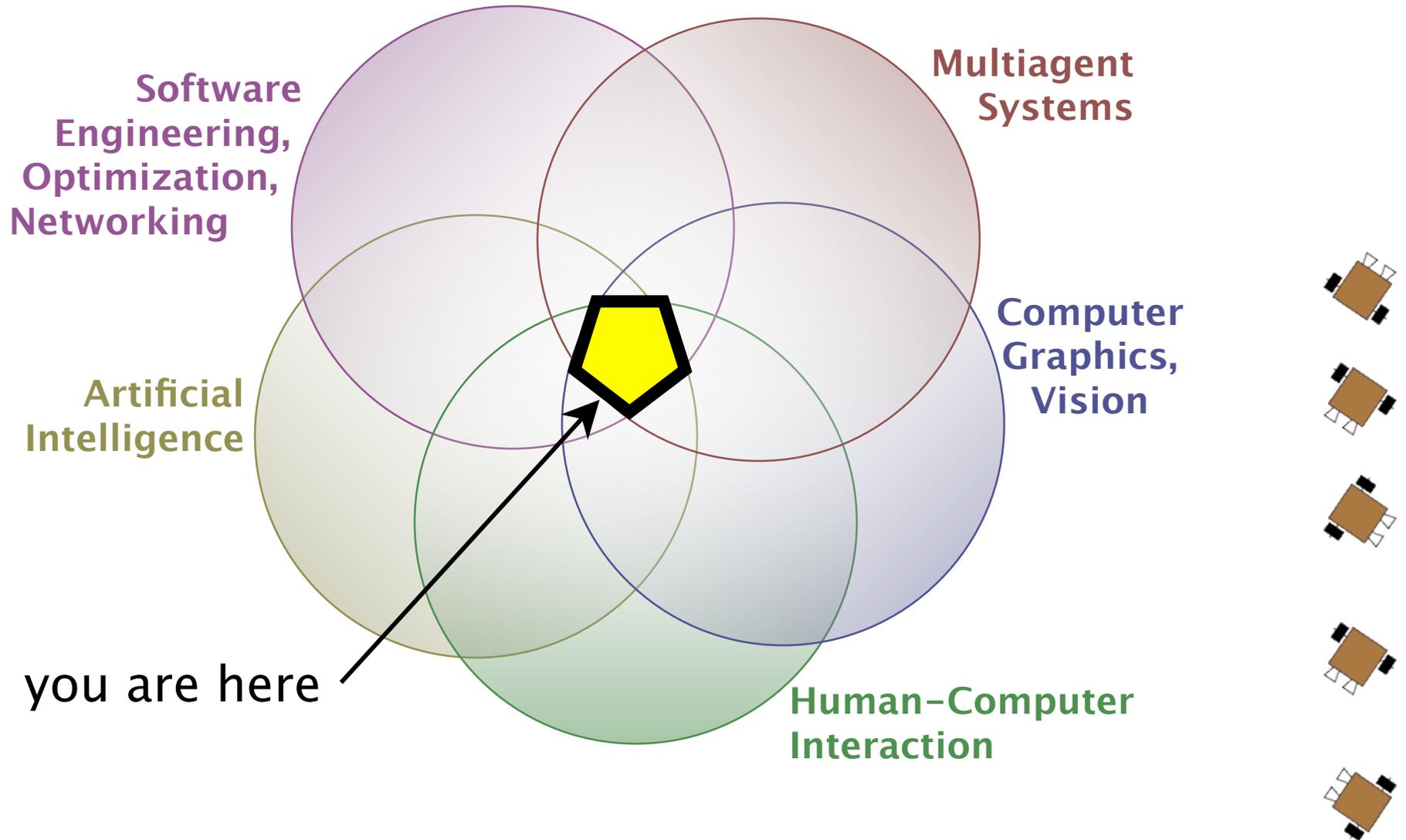


educational robotics

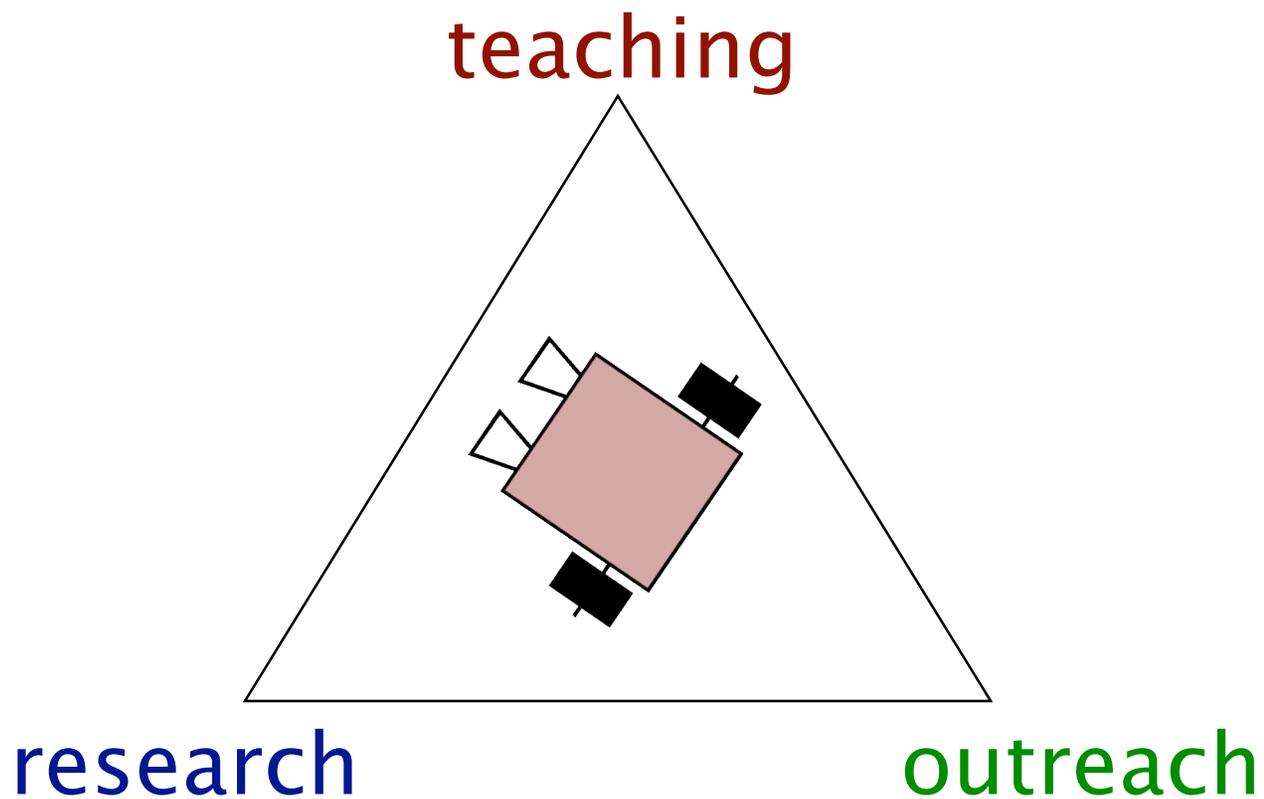
- the use of robotics for learning topics other than specifically *robotics*
- more obvious topics:
 - mechanical and electrical engineering
 - computer science and engineering
 - engineering design; physics
- less obvious topics:
 - mathematics; writing
 - scientific method; lab skills
 - communication skills, teamwork



what aspects of CS are involved?



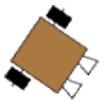
three aspects of educational robotics



situated learning:

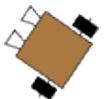
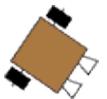


- since 1997, international research initiative designed to bring AI and robotics researchers together
- annual competition and academic conference
 - Osaka 2005: 1200 participants in 400 teams from 35 countries
- leagues:
 - soccer: small, midsize, 4-legged, humanoid, simulation
 - rescue: “real”, simulation
 - junior: soccer, rescue, dance



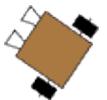
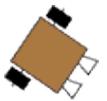
RCJ mission and goals

- to create a learning environment for today and to foster understanding among humans and technology for tomorrow
- naturally shares the overall RoboCup mission: to unite AI and robotics researchers around the world to solve a common problem
- encourages teamwork and project-based learning, development of communication and time management skills, in addition to traditional academic areas like engineering and programming
- de-emphasizes competition and emphasizes inter-team cooperation, dialogue and sharing



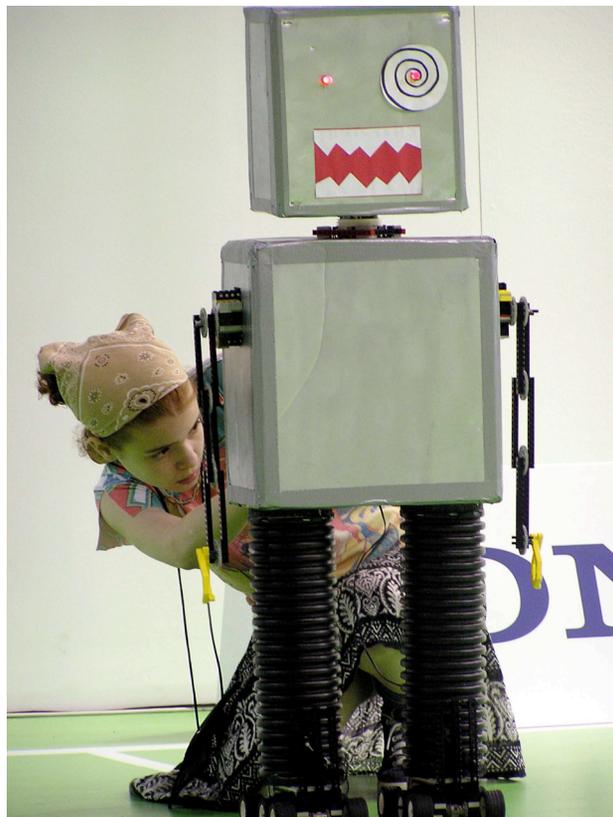
brief history of RoboCupJunior (RCJ)

- **soccer** game first demonstrated at RoboCup 1998 by Lund and Pagliarini
- RCJ founded as an international competition at RoboCup-2000 in Melbourne, Australia
 - three challenges introduced:
 - **dance**
 - **sumo** (line-following)
 - **soccer**
- **rescue** challenge introduced at RoboCup-2003 in Padova, Italy (replaced sumo)
- **superteams** introduced in soccer at RoboCup-2005 and in rescue at RoboCup-2006
- RoboCup-2007 will be in Atlanta, USA



RoboCupJunior: dance

one (or more robots),
static environment, no
sensors required,
creativity encouraged



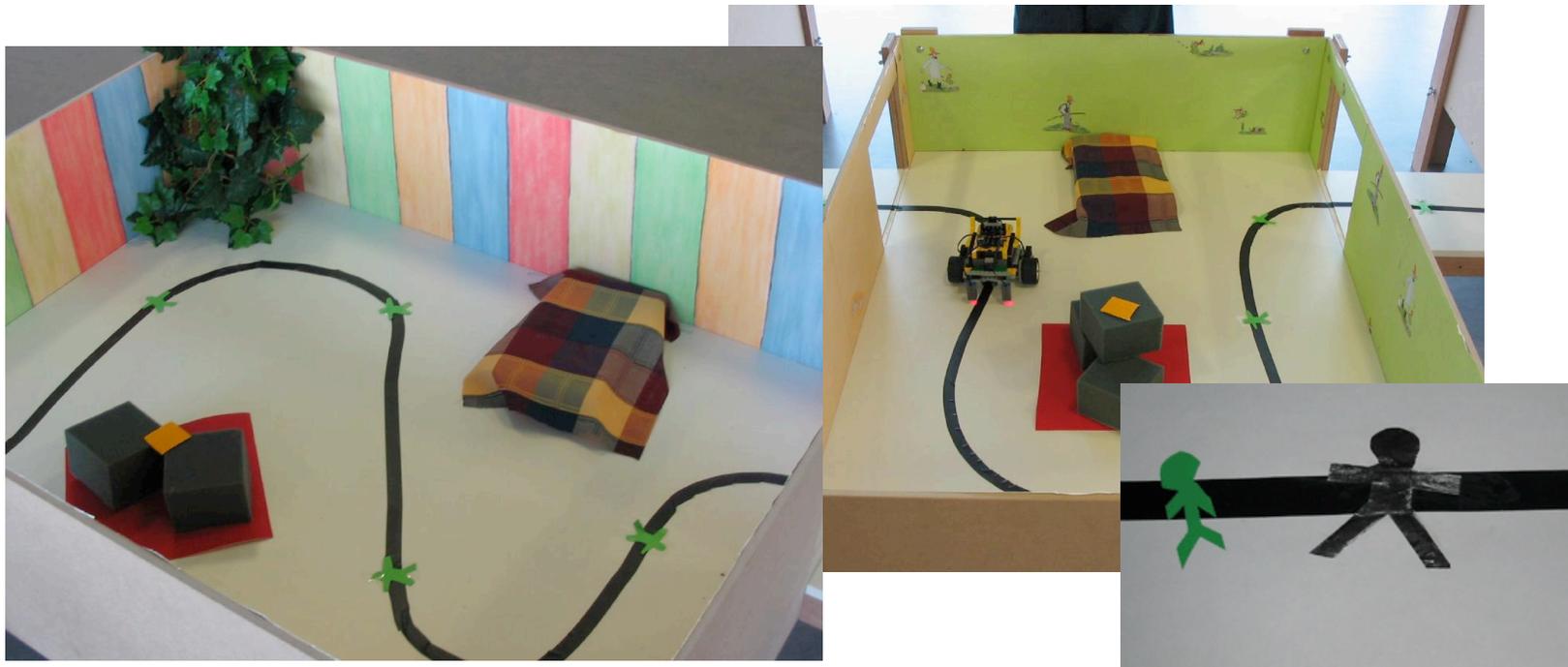
RoboCupJunior: rescue



one robot, static environment, light sensor required,
touch sensor helps

teams can design the interior of their own modules;
doorways are placed in standard locations; line varies

new in 2007: yellow, orange and red modules



RoboCupJunior: soccer



2x2 robot games, highly dynamic environment, light sensor required, touch sensor helps



RoboCupJunior participation

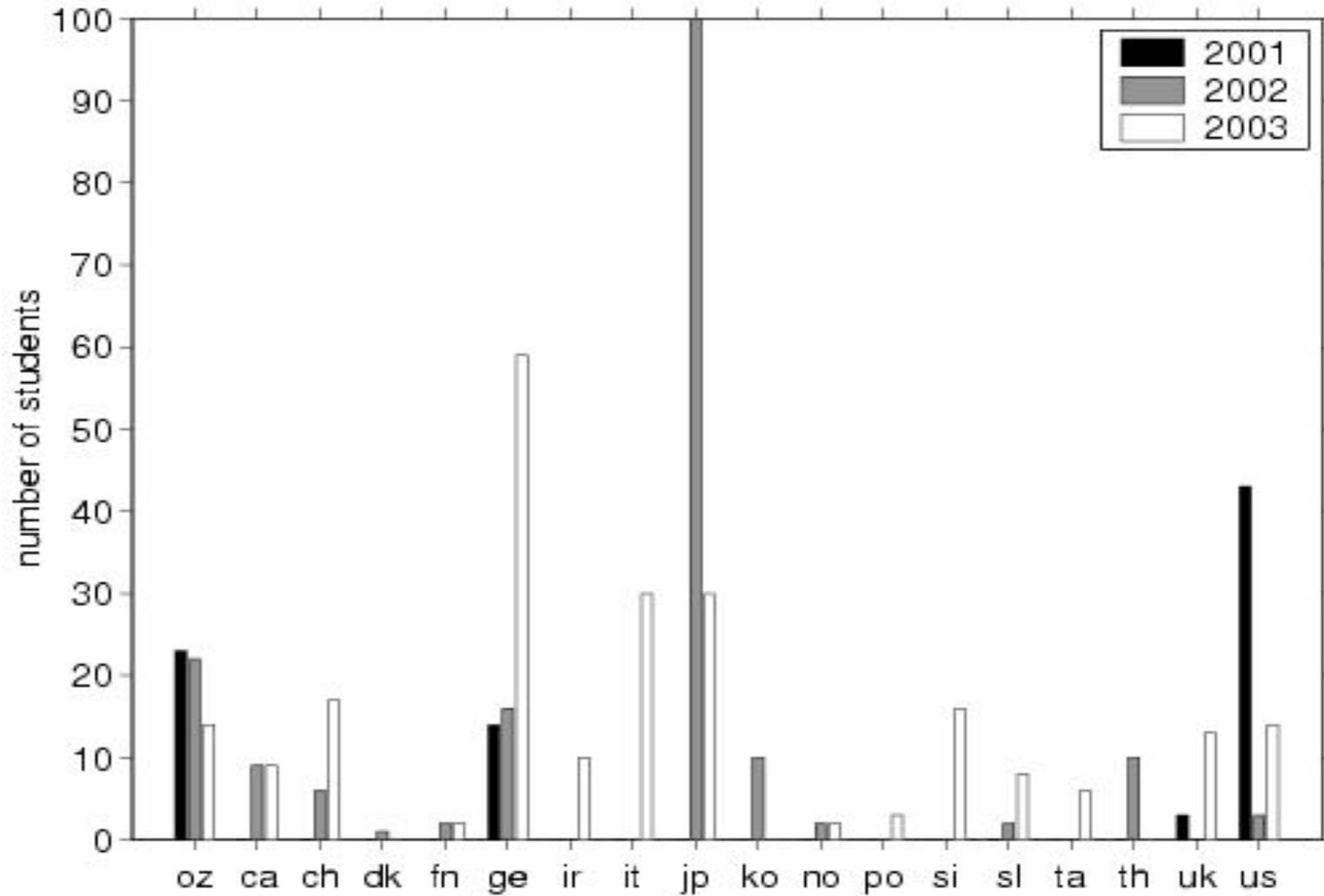
(2000–2006)

	2000	2001	2002	2003	2004	2005	2006
teams	25	25	59	67	162	163	240
students	~100	83	183	233	677*	588*	~1000
mentors	~25	17	51	56			
countries	3	4	12	15	18	18	22



*no stats available on student/mentor breakdown

geographic distribution of teams (2001-2003)



challenges and gender distribution

(2001–2003)

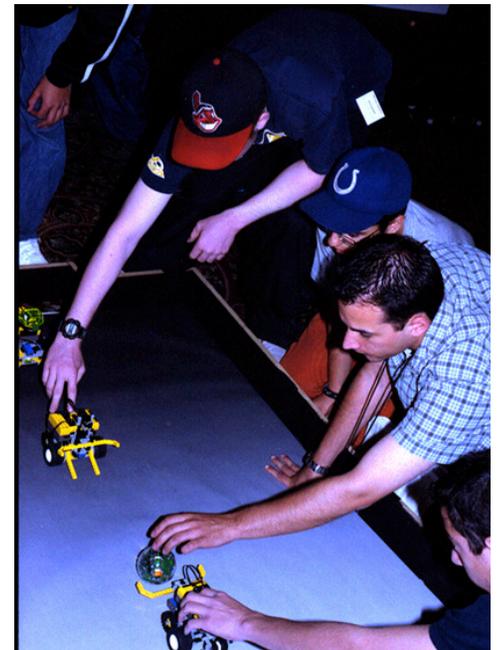
	2001 students	% female	2002 students	% female	2003 students	% female
dance	29 (35%)	17%	63 (34%)	25%	67 (29%)	33%
rescue	16 (19%)	0%	n/a	n/a	39 (17%)	18%
1x1 soccer	n/a	n/a	10 (5%)	0%	49 (21%)	6%
2x2 soccer	68 (82%)	10%	125 (68%)	13%	166 (71%)	8%



broadening educational robotics

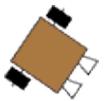
- provides a hands-on medium for *constructionist* learning
- tremendously motivating
- students are learning without realizing they are learning...
- and it's really fun!
- pedagogically, students are “learning by doing”, through experimentation — the result is greater understanding

[Goldman, Eguchi & Sklar, 2004; Sklar, 2004]



teaching

- use robots as a hands-on tool for non-robotics classes:
 - introductory computer science (for non-majors)
 - introduction to programming (for majors)
 - data structures
 - object-oriented programming
 - introduction to artificial intelligence
 - introduction to robotics
 - introduction to multiagent systems
 - service learning ⇒ **outreach**
- motivates students
- provides physical experimentation base for abstract concepts
- teaches about optimization and efficiency



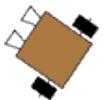
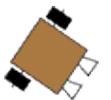
teaching: introductory computer science (for non-majors)

- creative thinking
- step-wise, process-based, algorithmic thinking
- documentation, project management, teamwork
- technical literacy concepts:
 - feedback
 - finite state machines, Markov processes
 - knowledge representation, reasoning under uncertainty
- environment:
 - LEGO Mindstorms (RCX), RoboLab (GUI)



teaching: introduction to programming (for majors)

- general programming concepts:
 - branching, looping
 - data structures, knowledge representation
 - algorithms
- debugging, documentation, project management, teamwork
- environment:
 - LEGO Mindstorms (RCX), lejos (Java)



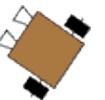
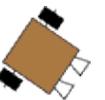
teaching: artificial intelligence

- concepts:
 - agency
 - deliberative, reactive, behavior-based and hybrid control
 - machine vision
 - heuristic and adversarial search
 - knowledge-based representation
 - propositional and predicate logic
 - common-sense reasoning
 - means-end and partial-order planning
 - perceptrons, neural networks, evolutionary and reinforcement learning
- environment:
 - LEGO Mindstorms (RCX), NQC (C-based)



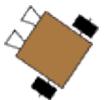
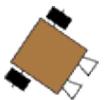
teaching: intro robotics

- locomotion
- behavior-based robotics
- kinematics
- perception
- localization
- navigation & planning
- environment:
 - LEGO Mindstorms (RCX), BrickOS (C++/C-based)
 - Sony AIBO, C++



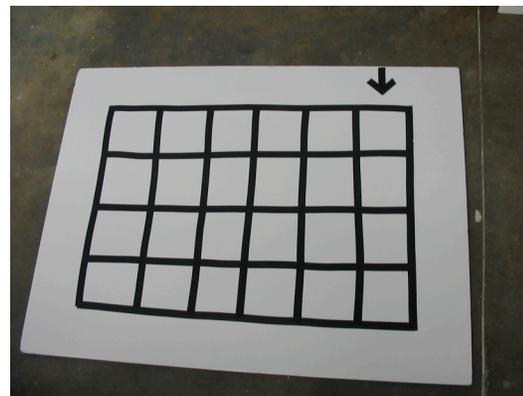
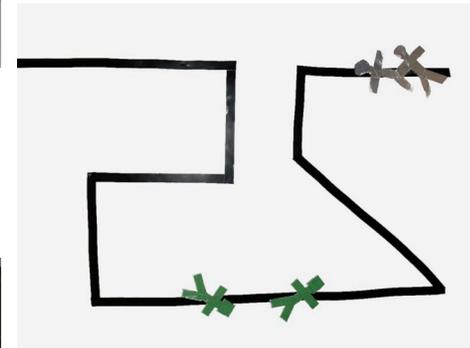
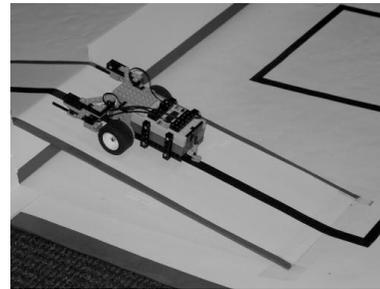
teaching: multiagent systems

- autonomous agents
- agent architectures
- agent communication and teamwork
- distributed, rational decision making; auctions
- agent modeling
- multiagent learning
- swarms and self-organization
- applications, entertainment, case studies
- environment:
 - LEGO Mindstorms (RCX), NQC
 - Sony AIBO, C++



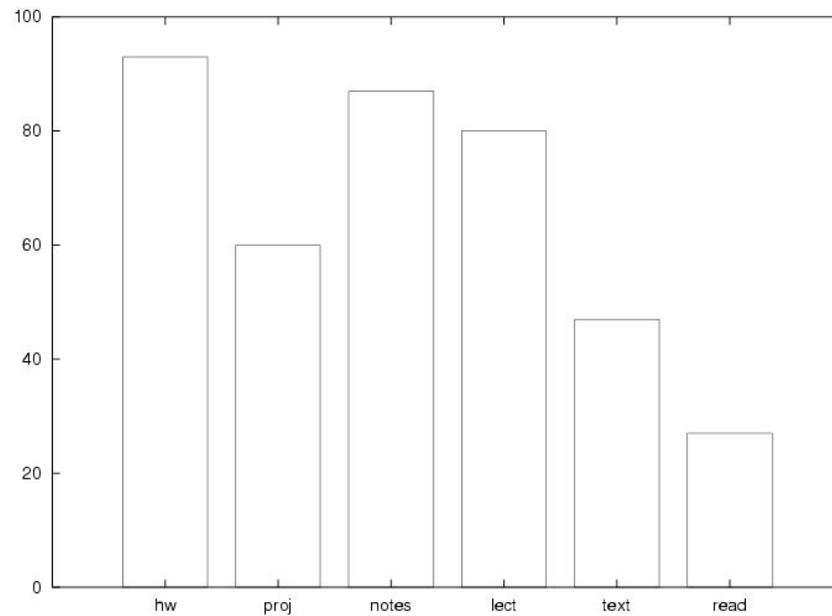
teaching: projects

- RoboCupJunior challenges:
 - rescue
 - soccer
 - dance (extra credit)
- competitive: pursuit race
- collaborative: relay
- flocking
- guarding the nest



teaching: evaluation

- Asked students how they felt different aspects of the course helped learning:

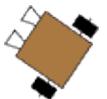


- Typical results across many offerings of AI



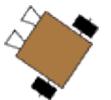
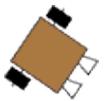
teaching: lessons learned

- make explicit connections between course material (lectures, reading, homework) and projects
- assess teamwork carefully and fairly
- build lab time into the course schedule
 - you lose time but you win overall
- the more you scaffold, the further they get
- competitions make a good climax to projects
 - structure competitions so that everyone has fun
 - small prizes are a great motivator
 - performance doesn't count toward course grade



research

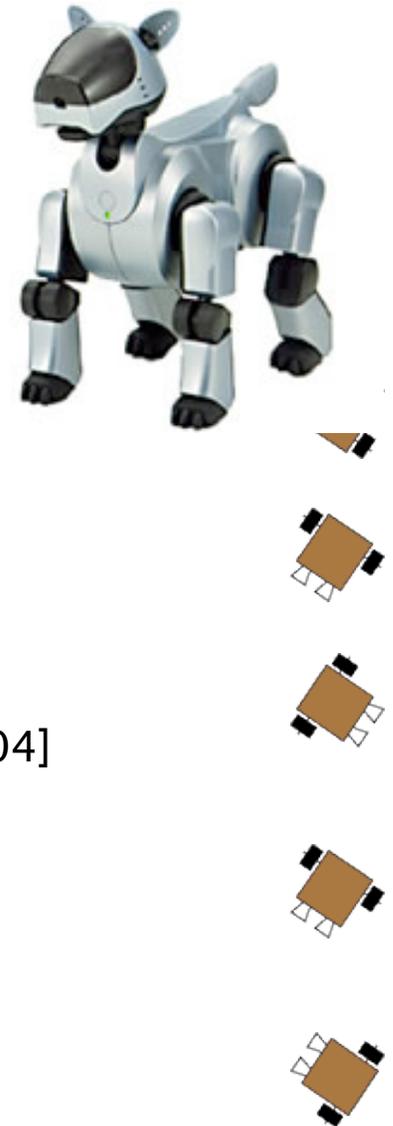
- metroBots
- eLeague
- educational assessment: what are they learning?
- integrated development and testing environment for learning



research: metroBots

- teams of Sony AIBO robots play soccer
- problems of perception and calibration, localization, coordination and control
- experimenting with mechanism design techniques and evolutionary computation methods to *learn* strategies for effective interaction and coordination

[Frias–Martinez, Sklar & Parsons, 2003; Frias–Martinez & Sklar, 2004]



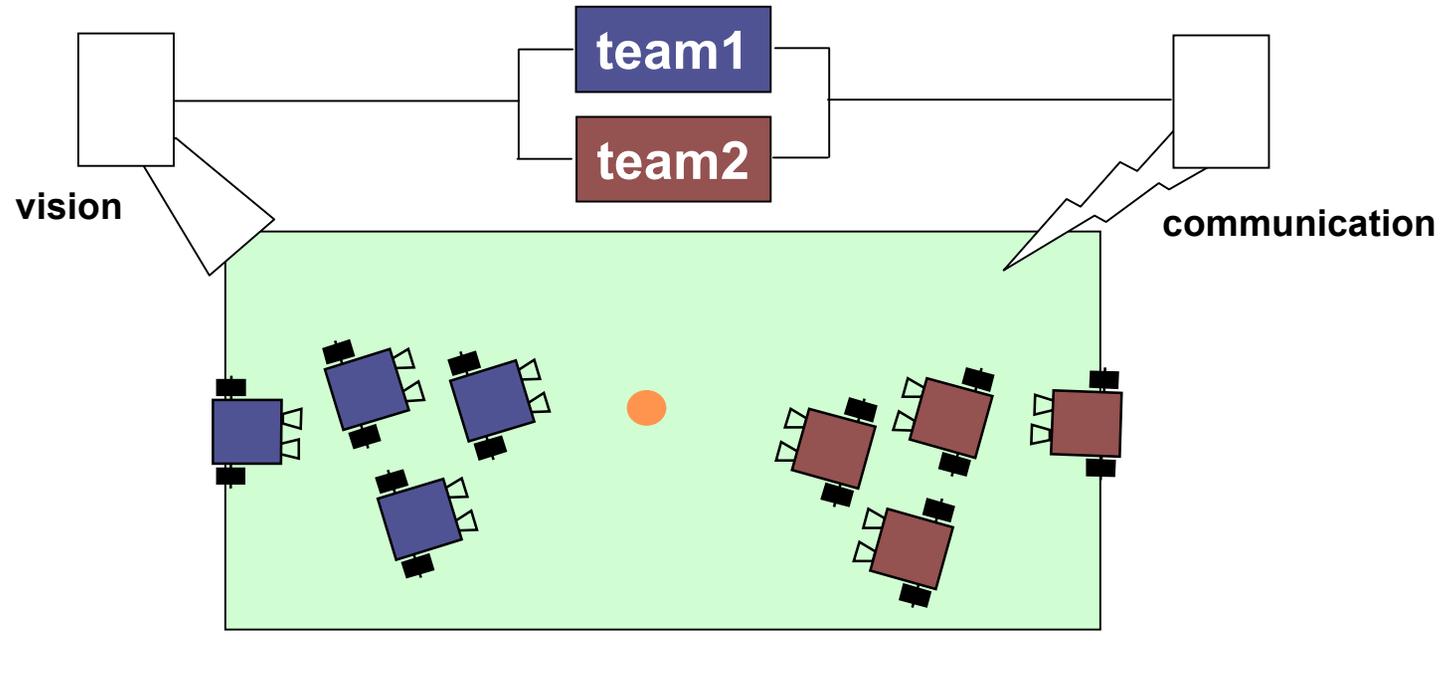
research: eLeague

- bridge the gap between RoboCupJunior and RoboCup Small-sized league

[Anderson, Baltes, Livingston, Sklar and Tower, 2003;

Baltes, Sklar and Anderson, 2004;

Imberman, Barkan and Sklar (submitted)]



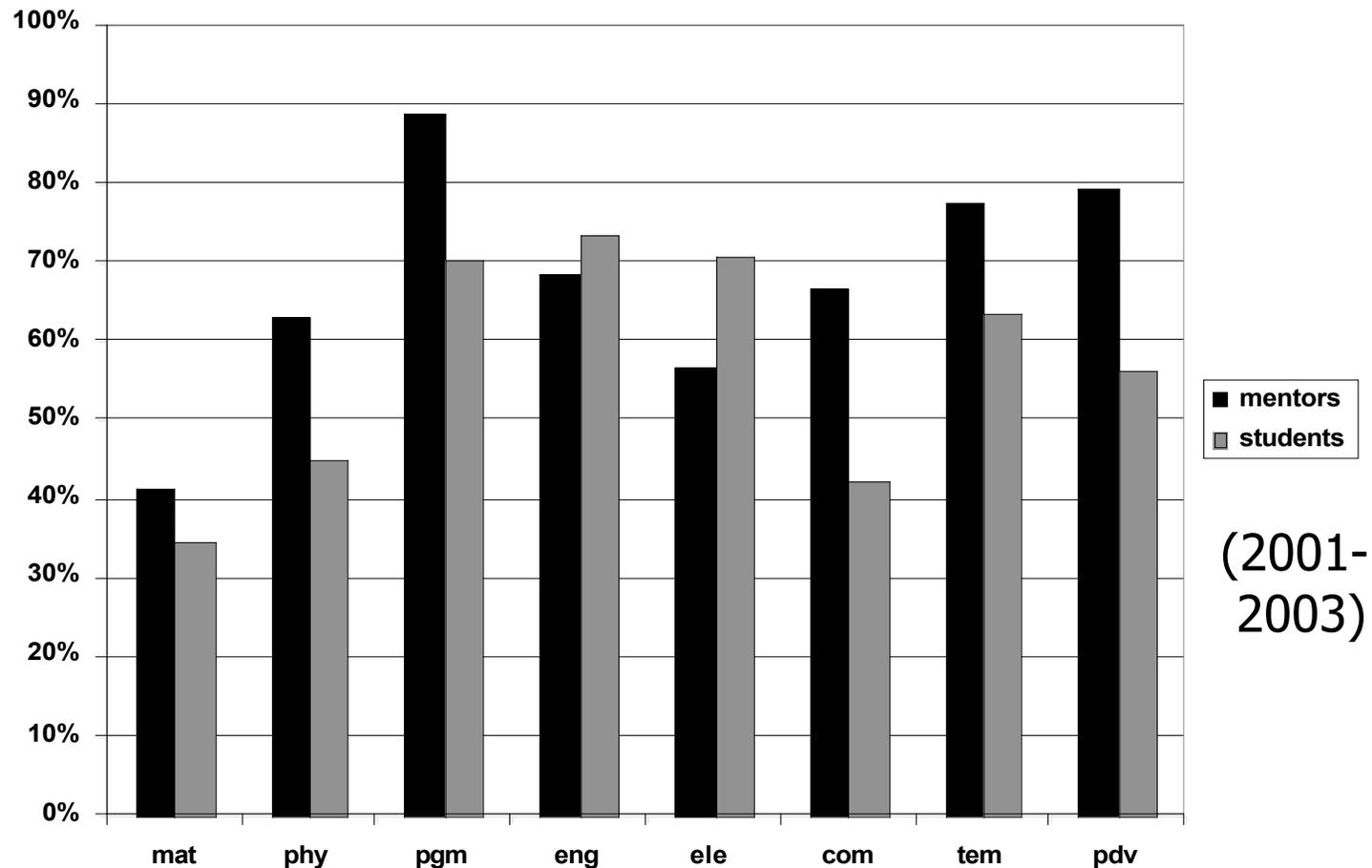
research: what are they learning?

- hard question!
- are they learning the curriculum too?
- is the robotics helping the students learn?
- is the robotics helping to motivate the students?
- the students are learning:
 - engineering
 - programming
 - design
 - teamwork
 - communication skills



research: RCJ evaluation studies (2000-04)

- involvement in RCJ has had a positive effect on...



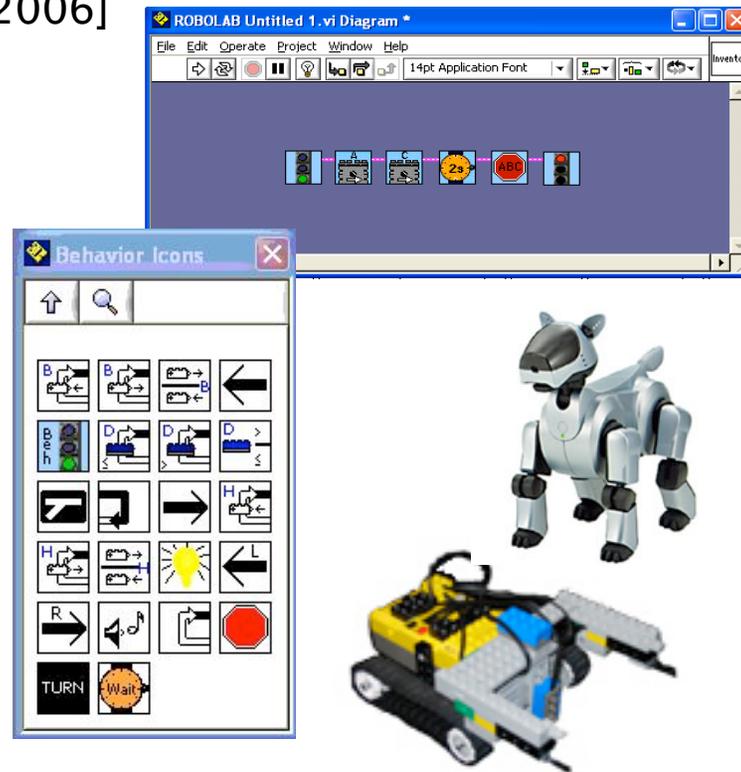
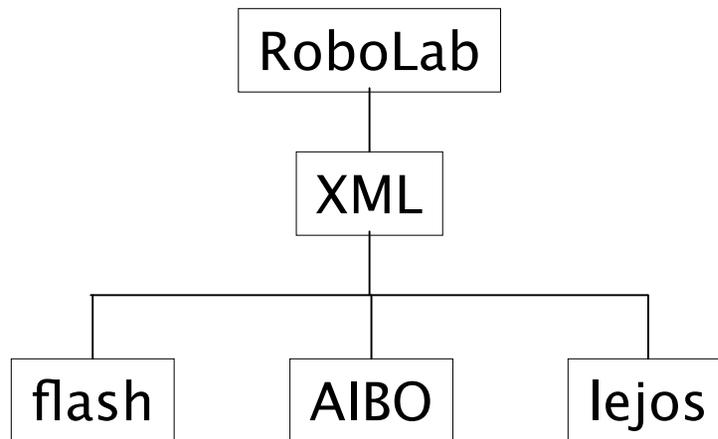
[Sklar, Eguchi & Johnson, 2002; Sklar & Eguchi, 2004]



research: integrated development and testing environment for learning

- construct a universal educational robotics IDE
- goal: multiple entry points, multiple exit points

[Chu, Goldman & Sklar, 2005; Goldman 2005; Goldman, Azhar & Sklar, 2006; Azhar, Goldman & Sklar, 2006]



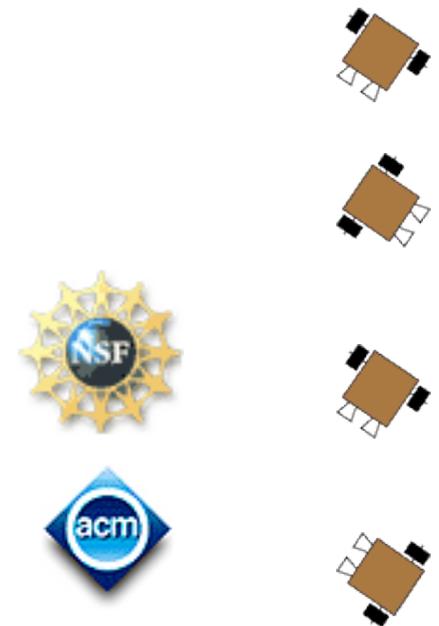
outreach: robotics.edu

- work with classroom teachers to introduce robotics:
 - focus on learning by design
 - exploration
 - introduction of technical terms
 - promote comfort with technology
 - teamwork
 - typically math and/or science teachers
 - typically need a double period (i.e., ≥ 90)
- supported by undergraduates (service learning)
- supervised by faculty and phd students



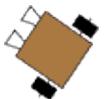
outreach: activities

- who?
 - students — late primary and middle school, high school, undergraduate; 80–100% male
 - mentors — classroom and afterschool teachers, community center leaders, parents, older students, university faculty; more gender balanced, but > 50% male
- where?
 - schools, camps, community centers, labs, universities
- how?
 - teacher training, structured curriculum, inexpensive and re-usable equipment



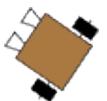
outreach: primary/middle school

- methodology:
 - learning by design and exploration
- goals:
 - introduction of technical terms
 - comfort with technology
 - teamwork
- typically math and/or science teachers
- typically need a double period (≥ 90 min)
- 6-step curriculum:
 - bridge \rightarrow simple go-cart \rightarrow simple crane \rightarrow programmable crane \rightarrow programmable go-cart \rightarrow robot



outreach: progressive curriculum

- ! bridge
 - basic building blocks
- ! simple go-cart
 - wheels and gears
- ! programmable go-bot
 - motors
 - looping
 - touch sensor
 - light sensor
 - branching

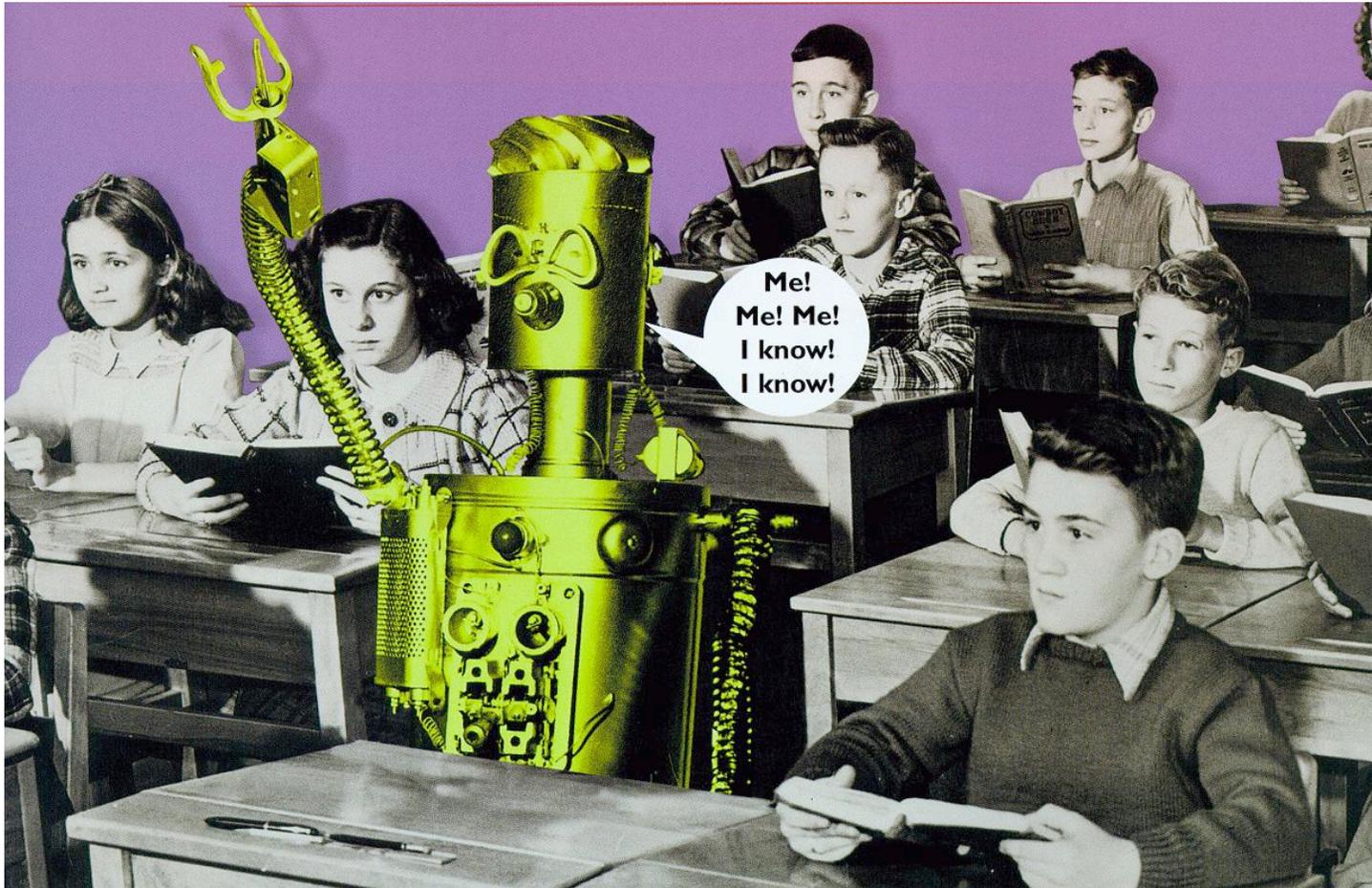


outreach: high school

- less freedom with curriculum
- more standardized testing
- less time
- bigger hurdles
- but bigger rewards
- girls don't play games



educational robot?



[<sklar@sci.brooklyn.cuny.edu>](mailto:sklar@sci.brooklyn.cuny.edu)

