Features of Intelligent Tutoring Systems

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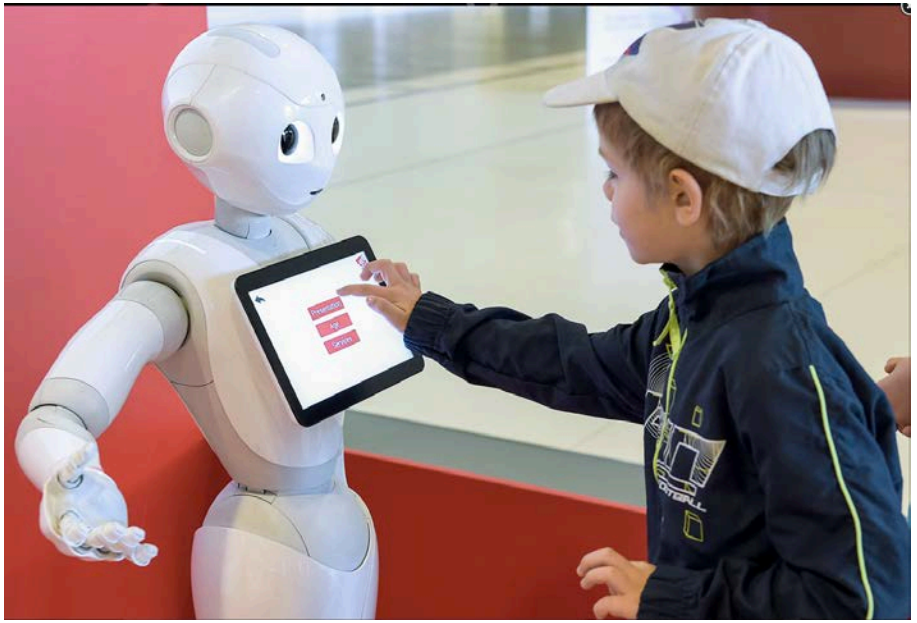
AGENDA

- Motivation
- Emotion in Learning
- Collaboration
- Intelligent Training
- Big Data for Education

AI in Education

Using AI technology, (machine learning, natural language processing, planning, etc.) to provide real-time personalized feedback to students.



Detects whether a student's reaction to a concept follows a pattern (e.g., has a skill or a misunderstanding).
Provides an early warning for teachers and self-regulation aids for students.

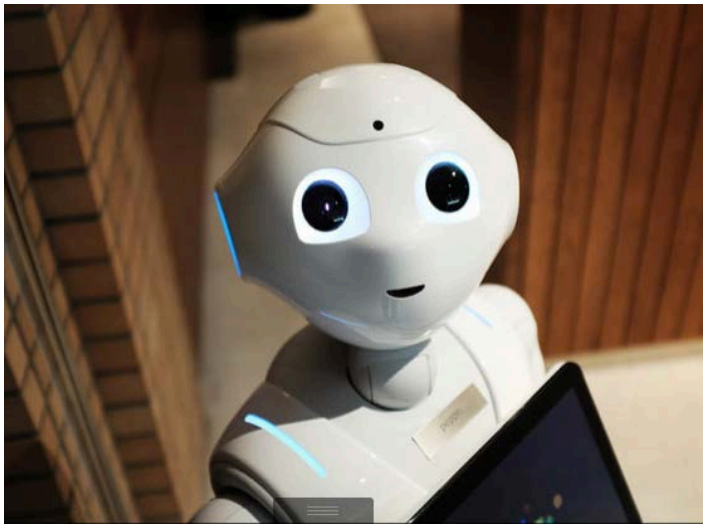
Function of AI in Education

- **Personalized Learning**

  Analyze student data (course work, interactions, test scores etc.) to create a unique and customized learning path for students.

- **Real time performance tracking**

  Leverage AI to track performances and offer feedback tailored to each student.



First humanoid robot to be adopted in Japanese homes, a multipurpose human-shaped robot.

- **Customized Smart Content**

  Customize content to suit the needs of learners. Break content into easy parts, add multimedia and incorporate tests adapted to each new user.

Intelligent Tutors

- AI-enabled software helps teach basic skills so that educators can focus on more complex topics.
- Sentient tools can take over simple and social tasks that teachers and aids provide today.
- One potential of AI is to automate menial tasks so that teachers will have less drudgery, e.g., grading.
- AI might provide more time for teachers to create engaging and creative activities, and work on their own professional development.

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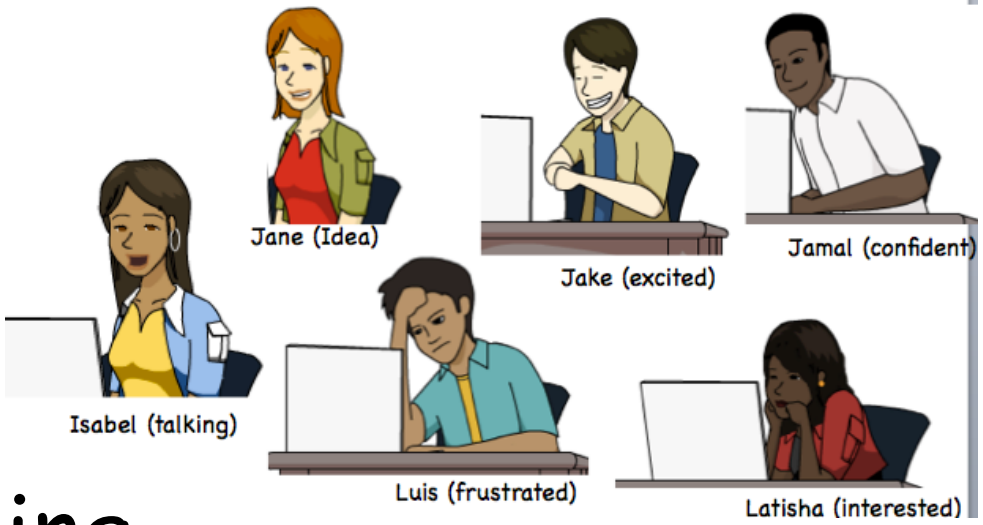


Motivation

→ Emotion in Learning

Collaboration

Intelligent Workplace Training

Big Data for Education

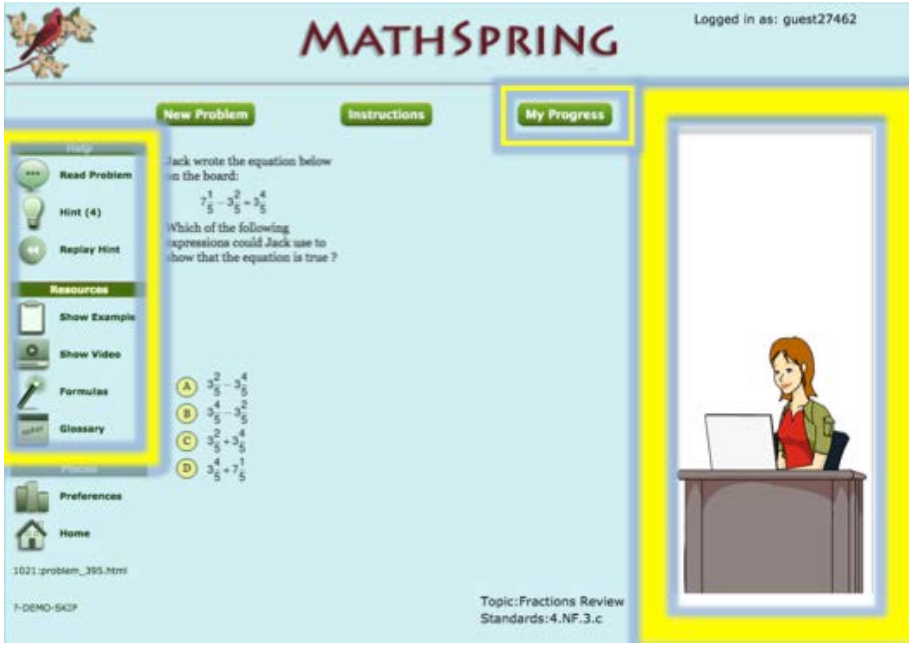
Learning is Impacted by Emotion

- Predispositions (low self-confidence) can diminish success. Boredom reduces task performance.
- Positive emotions (confidence) have an impact on learning performance.

D. Goleman. Emotional intelligence. why it can matter more than fq. *Learning*, 24(6):49–50, 1996.
R. Pekrun, T. Goetz, L. M. Daniels, R. H. Stupnisky, and R. P. Perry. Boredom in achievement settings: Exploring control-value antecedents and performance outcomes of a neglected emotion. *Journal of Educational Psychology*, 102(3):531, 2010.

Students Express Emotion

- What should a tutor do in the moment when students are frustrated, bored, etc.?
  - Increase Challenge? Decrease Challenge?
  - Provide "affective" scaffolds? What are those?
  - Suggest peer-to-peer collaboration?



How to measure changes in student affect, capturing micro-changes in student affective states after an intervention?

Three Responses Were Evaluated

Empathy	"Don't you sometimes get frustrated trying to solve math problems? I do."
Growth Mindset	"Did you know that when we practice to learn new math skills our brain grows and gets stronger?"
Success / Failure	"Very good, we got another one right!"

Dweck Growth Mindset

- Students who believe that intelligence can be increased tend to seek out academic challenges.
- Growth mindset messages lead to improved learning
- D'Mello found successful results in Auto-Tutor using Empathy,

D'Mello et al., 2010

Observations

- Students exhibited higher levels of interest and valued math knowledge more with exposure to more empathic messages.

- Students valued math knowledge less and had lower post test performance score, with growth mindset messages.

- Students were less learning-oriented and more confused with success/failure messages

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Collaboration Research

Collaboration is **student-centered; students:**

- **are active,**
- **pose** questions,
- **explain** topics/concepts to their peers,
- **interact** with one another.

Johnson, & Johnson,. (1989). *Cooperation and competition: Theory and research*. Interaction Book Company

Johnson, & Johnson (2005). New developments in social interdependence theory. *Genetic, social, and general psychology monographs*, *131*(4), 285-358.

Collaboration

Collaboration impacts cognitive and affective outcomes:

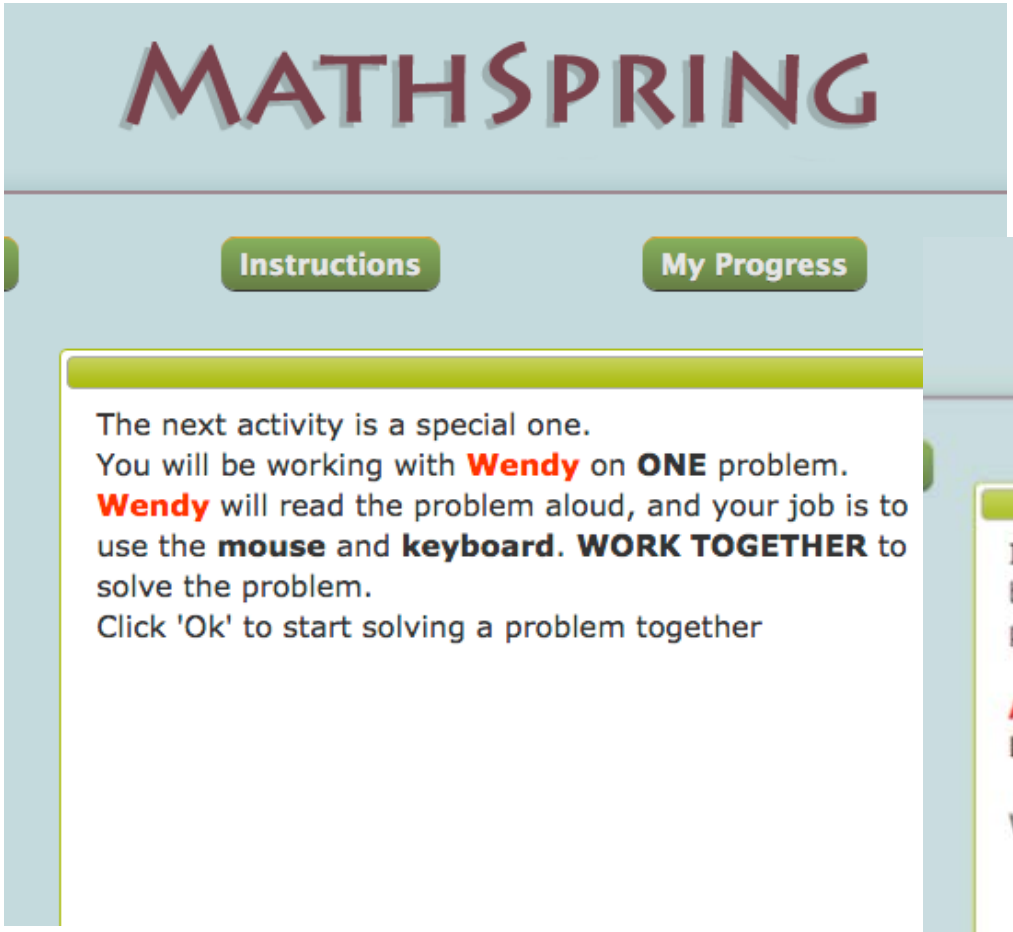
- Increases achievement in standardized test scores as compared to control groups, with large effect sizes
- Produces novel ideas and learning gains **beyond the ability** of the best individuals in the group
- Produces knowledge that **none of its members** would have produced on their own.

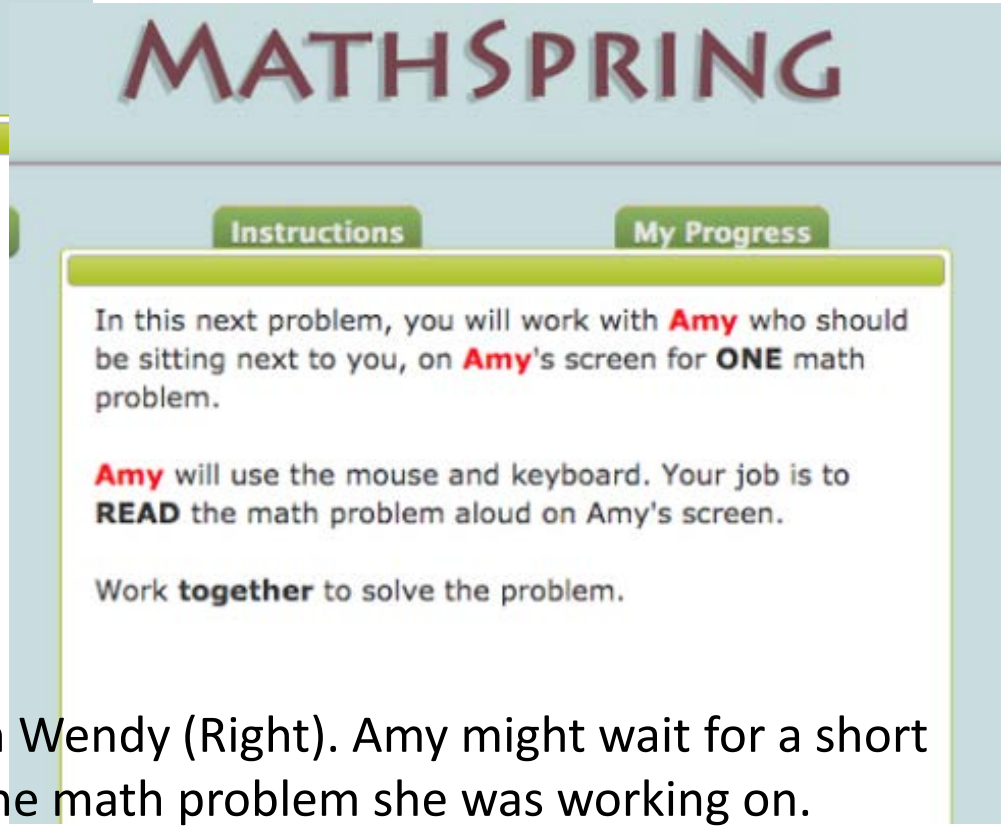
Peer-to-peer interactions are vital aspects of collaboration,

- Students question processes, make mistakes, and monitor each other's reasoning.

Slavin, R., Lake, C., & Groff, C. (2009). Effective programs in middle and high school mathematics: A best-evidence synthesis. *Review of Educational Research*, *79*(2), 839-911.
Slavin, R. (1990). Cooperative learning: Theory, Research, & Practice. Englewood Cliffs, NJ, Prentice-Hall.

Peer-to-peer collaboration





(Left) Invitation to Amy to work with Wendy (Right). Amy might wait for a short time until Wendy completed the math problem she was working on. Special roles are assigned to each student. After students solved the problem together on Amy's screen, they worked on their own computers.

Team Activities

- Team activities often increase students' interest.
- Peer-to-peer activities address students' negative affective states.
- Collaboration provides a boost in student math learning.
- Collaboration yields higher math performance and learning.

In Summary

- Peer–to-peer collaboration:
  - increases students' interest.
  - responds to students' negative affective states.
  - provides a boost in student math learning.
  - yields higher math performance and learning.

Discussion

- We refined a methodology to analyze how peer-to-peer collaboration produces changes in affective states
  - Randomized Controlled trials → Model creation/application
- Evidence that offering collaboration can lead to increased interest and excitement

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The Need to Train Soft Skills

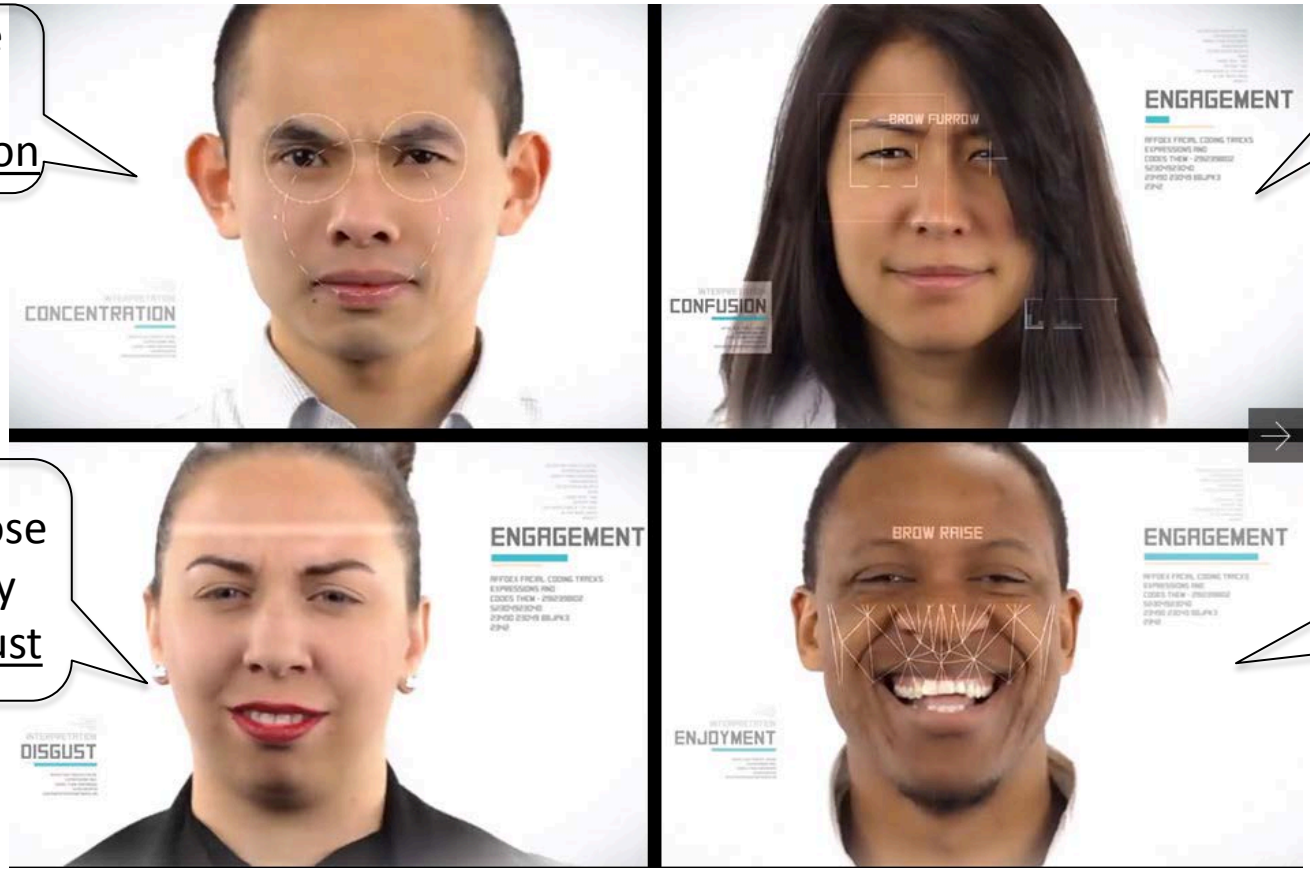
- Job growth in the United States required relatively high degrees of social skills. Jobs requiring high levels of social interaction grew by nearly 12 % points.
- Math-intensive but less social jobs - including many STEM occupations - shrank by 3.3 % points over the same period.
- The labor market's return to social skills was greater in the 2000s than in the mid 1980s -1990s.
- Corporate hiring favors social skills (Gershon, 2016) . Soft skills can make the difference between a standout trainee and one who just gets by.

Which Skills to Train?

Team Activities	Soft Skills Required
Receive Information	• Listening Skills • Analytic Thinking
Respond to Information	• Ability to Communicate Effectively • Leadership Skills • Problem-Solving
Value Others	• Diplomacy • Flexibility
Organize People	• Change-readiness • Team-building Skill
Characterize Activities	• Self-awareness • Creativity

These soft skills are deemed to be behaviors critical to effective performance in the workforce and are suggested to be in short supply.

Tracking Workers Facial Cues



Fixed stare signals concentration

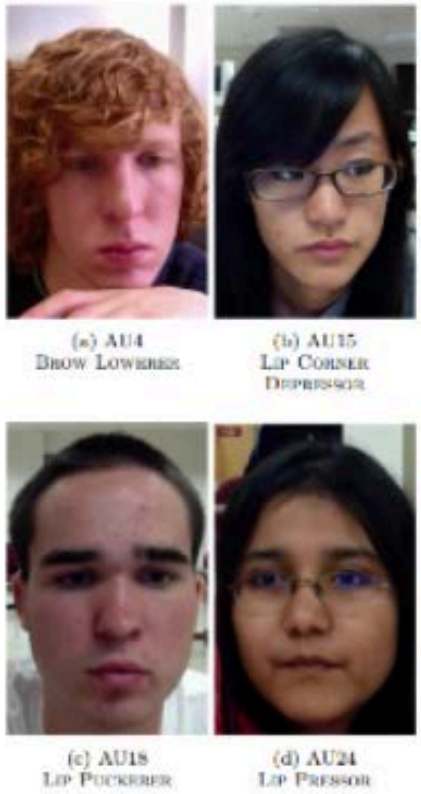
Furrowed brow signals confusion

Wrinkled nose bridge may signal disgust

Raised brow signals enjoyment

Screenshots from a video from Affectiva shows how the Affdex software tracks facial cues to infer emotions.

Primary message



1. Facial expressions for women and men differ systematically during learning, that is, men and women have different ways of affectively expressing internal states (moments of mental effort and uncertainty)

1. Gender specific models may support students more effectively

Alexandria Vail, Joseph Grafsgaard, Kristy Boyer, Eric Wiebe, James Lester, UMAP 2016

Facial Expression Differences by Gender

(a) AU4 Brow Lowerer (b) AU15 Lip Corner Depressor

(c) AU18 Lip Puckerer (d) AU24 Lip Pressor

- Female students tended to express **AU15 (Lip Corner Depressor)** more frequently than male students.
- Male students were more likely to express **AU4 (Brow Lowerer), AU18 (Lip Puckerer) and AU24 (Lip Pressor)**.

* investigated whether these differences arose due to other characteristics (incor

	Females	Males
AU4 Brow Lowerer	-0.536 ± 0.418	-0.133 ± 0.566
AU15 Lip Depressor	-0.499 ± 0.296	-0.786 ± 0.281
AU18 Lip Puckerer	-0.510 ± 0.590	0.136 ± 0.556
AU24 Lip Pressor	-0.353 ± 0.358	-0.051 ± 0.386

Predicting Learning from Facial Expression

Are Facial Action Units predictive of learning gain in male and female students?
Trained a step-wise regression model to predict learning gain.

Normalized Learning Gain =	R^2	p
+0.6508 * AU2 Outer Brow Raiser	0.2209	0.009
+1.2120 * AU9 Nose Wrinkler	0.1109	0.003
+1.7156 * AU12 Lip Corner Puller	0.1591	0.006
−0.7100 * AU20 Lip Stretcher	0.0908	0.005
−0.9414 (Intercept)		1.000
Leave-One-Out Cross-Validated $R^2 = 0.5817$		

4 facial expressions are significantly predictive of learning gain in female students.

Normalized Learning Gain =	R^2	p
−0.6628 * AU5 Upper Lid Raiser	0.1199	0.010
+0.1747 (Intercept)		1.000
Leave-One-Out Cross-Validated $R^2 = 0.1199$		

Only 1 facial expression is significantly predictive of learning gain in female students.

Facial Expression Differences by Gender

Discussion

- **AU15 (Lip Corner Depressor), AU18 (Lip Puckerer) and AU24 (Lip Pressor)** maybe associated with negative affect, and maybe indicative of moments of mental effort and uncertainty.
- **AU4 (Brow Lowerer)** has been acknowledged as a key indicator of mental effort or confusion in learning context, which is further reinforced here.

Discussion

- Different facial expression features important for predicting learning in male and female students.
- Interpretations of why AUs are predictive, e.g. Upper Lid Raiser (AU5) is the only AU found predictive of learning for male students
  - Male students opened eyes while being overwhelmed in the learning task
  - Widened eyes corresponded to greater amount of reading, but this was associated with extraneous cognitive processing resulting in less efficient learning
  - Eye widening was performed to stave off boredom

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Intelligent Workplace Training

→ Big Data for Workplace Training

Big Data in Workplace Training

Big Data . . .

- Identifies trainees with similar learning difficulties and gender differences.
- Tracks trainees' behavior by seconds: requests for help, carelessness, guessing, etc.
- Is essential to advance online instruction.
- Supports trainers to offer help, change course material or compliment the student.
- Helps interpret what trainees and trainers do in the classroom.

Log Data from Online Tutor

studId	emotion	level	explanation	tim
29077	Interest	3	its ok	20
29075	Interest	4	I had trouble in the last few problems	20
29014	Excitement	4	BECAUSE I ACTUALLY AM FEELING AS IM LEARNING	20
29073	Interest	5	Because math is my favorite subject and it's interesting solving new problems.	20
28993	Excitement	5	Cause	20
29004	Excitement	3	I am kind of excited because I am provided a lot of tools that can help me sole the problem	20
29075	Interest	5	I have been doing better	20
29018	Interest	3	its too hard!	20
29077	Excitement	4	its 0k	20
28998	Excitement	1	When people want to learn, they want to at less have fun while learning.	20
29000	Interest	3		20
29014	Excitement	5	I got it right	20
29006	Interested	4	because math is alright	20
29073	Interest	5	It is interesting solving new problems.	20
28991	Excitement	1	I am not feeling excited because math is not fun.	20
29016	Excitement	3	because well this is very not that hard then i tought i thought it was going To be very wierd then you	20

Large Data Sets

EventLog Table of a Math Tutoring System. 571,776 rows, just in a year time.

id	studId	sessNum	action	userInput	isCorrect	elapsedTime	probElapsed	problemId	hintStep	hin	emotio	activityName
179920	6858	26996	NextProblem	NULL	0	256675	7656	-1	NULL	NULL	NULL	askEmotionInter
179921	6858	26996	BeginInterventio	NULL	0	256847	0	-1	NULL	NULL	NULL	
179922	6858	26996	InputResponse	<userInput	0	274319	17472	-1	NULL	NULL	NULL	PracticeProblem
179923	6858	26996	EndIntervention	NULL	0	274631	0	-1	NULL	NULL	NULL	
179924	6858	26996	BeginProblem	NULL	0	277158	0	999	NULL	NULL	NULL	
179925	6858	26996	NextProblem	NULL	0	288950	11792	999	NULL	NULL	NULL	PracticeProblem
179926	6858	26996	EndProblem	NULL	0	289191	12033	999	NULL	NULL	NULL	
179927	6858	26996	BeginProblem	NULL	0	289709	0	171	NULL	NULL	NULL	
179928	6858	26996	Attempt	C	1	296821	7112	171	NULL	NULL	NULL	attempt
179929	6858	26996	NextProblem	NULL	1	302688	12979	171	NULL	NULL	NULL	PracticeProblem
179930	6858	26996	EndProblem	NULL	1	302901	13192	171	NULL	NULL	NULL	
179931	6858	26996	BeginProblem	NULL	0	303300	0	196	NULL	NULL	NULL	
179932	6858	26996	Attempt	A	1	391940	88640	196	NULL	NULL	NULL	attempt
179933	6858	26996	NextProblem	NULL	1	411065	107765	196	NULL	NULL	NULL	PracticeProblem
179934	6858	26996	EndProblem	NULL	1	411393	108093	196	NULL	NULL	NULL	
179935	6858	26996	BeginProblem	NULL	0	412766	0	16	NULL	NULL	NULL	
179936	6858	26996	EndProblem	NULL	0	415184	2418	16	NULL	NULL	NULL	
180017	6866	27006	NextProblem	NULL	0	507045	8949	-1	NULL	NULL	NULL	askEmotionInter
180018	6866	27006	BeginInterventio	NULL	0	507229	0	-1	NULL	NULL	NULL	
180019	6866	27006	EndIntervention	NULL	0	521987	0	-1	NULL	NULL	NULL	
180020	6866	27006	BeginProblem	NULL	0	524613	0	999	NULL	NULL	NULL	
180021	6866	27006	BeginText	NULL	0	532455	7842	999	NULL	NULL	NULL	
180022	6866	27006	EndText	NULL	0	533512	8899	999	NULL	NULL	NULL	
180023	6866	27006	Clear	NULL	0	533604	8991	999	NULL	NULL	NULL	
180024	6866	27006	Undo	NULL	0	534204	9591	999	NULL	NULL	NULL	
180025	6866	27006	BeginDrawing	NULL	0	535168	10555	999	NULL	NULL	NULL	
180026	6866	27006	NextProblem	NULL	0	539984	15371	999	NULL	NULL	NULL	PracticeProblem
180027	6866	27006	EndProblem	NULL	0	540191	15578	999	NULL	NULL	NULL	
180028	6866	27006	BeginProblem	NULL	0	540714	0	171	NULL	NULL	NULL	
180029	6869	27007	BeginProblem	NULL	0	5188	0	999	NULL	NULL	NULL	
182253	5658	27063	BeginProblem	NULL	0	11970	0	171	NULL	NULL	NULL	

Questions Trainers Ask

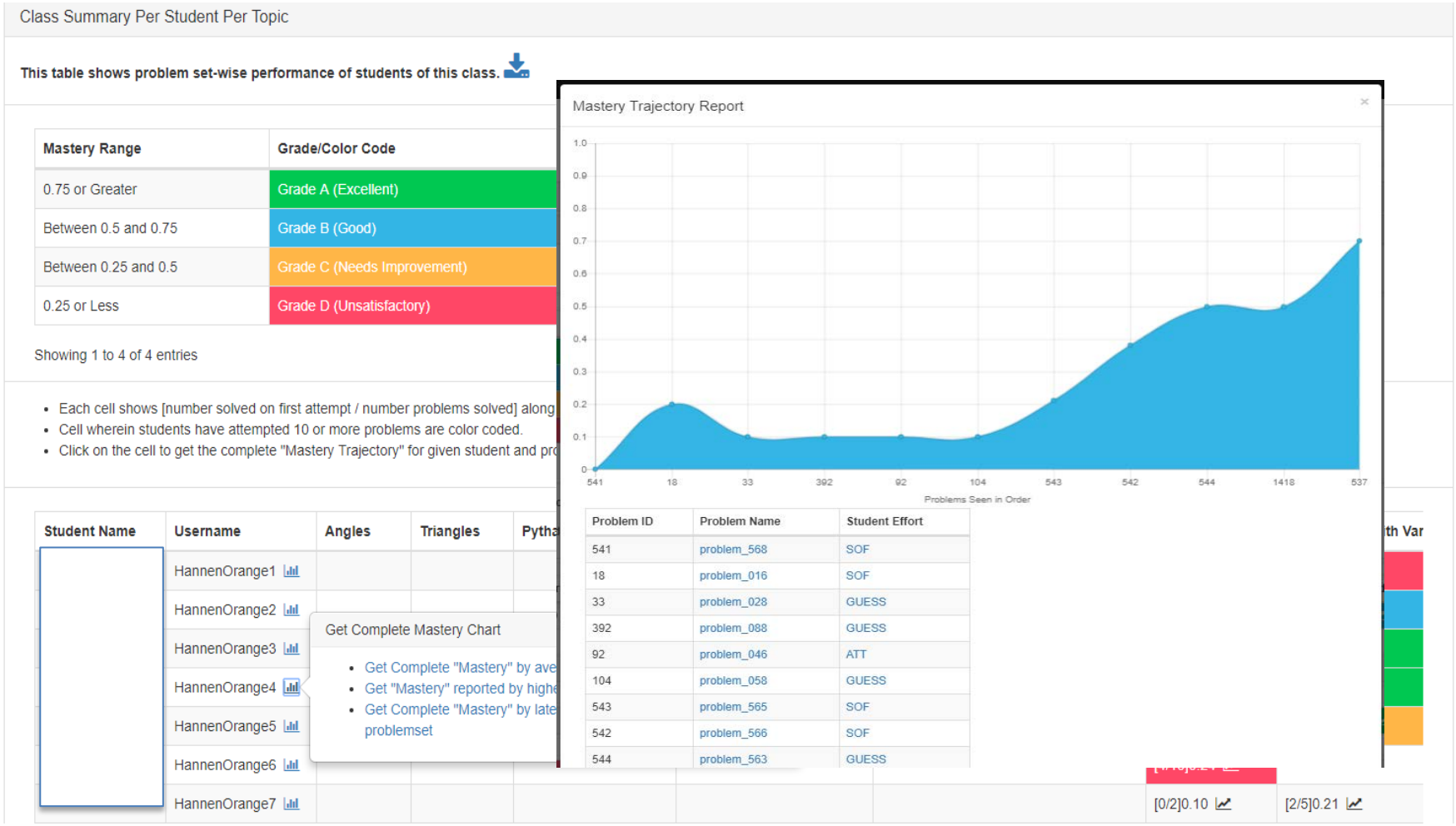
- How much trainees **KNOW**, **GAPS** questions
- **ACTING** and TRAINEES EFFECTIVELY questions
- How to have trainee become **effective LEARNERS** (Self-regulation/metacognition) questions
- Trainees' **MOTIVATIONS** questions
- **Tech. EFFECTIVENESS** and ENGAGEMENT with technology questions

Output to Trainees

Teachers can discern a strong/weak student

Username	No of problems attempted	Effort Chart
weakstudent1	227	

Report Per Problem Topic



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Any Questions ?

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Gender Differences in Facial Expressions of Affect During Learning

Vail et al.,

2016 Conference on User Modeling Adaptation and Personalization. ACM, 2016.

Alexandria Vail, Joseph Grafsgaard,Kristy Boyer, Eric Wiebe, James Lester