

Adaptive Learning Systems

EDUC 5100 | Fall 2022

Guest lecture by Elizabeth Cloude

Welcome!

- Brief introduction

Please call me Liz!

I study how humans self-regulate their learning by measuring cognition, emotions, metacognition, and motivation during learning with educational technologies including ITSs.

- Example: MetaTutor (which we will be discussing today!)



Today's discussion

- Intelligent tutoring systems built to scaffold metacognition and self-regulated learning (SRL) skills
 1. Help Tutor, an ITS for scaffolding help seeking (Aleven et al., 2016)
 2. MetaTutor, an ITS for scaffolding SRL (Bouchet et al., 2016)

Today's discussion cont'd...

- First, what is metacognition and self-regulated learning (SRL)?
- Second, why does it matter that learners demonstrate metacognition and SRL skills?
- Finally, how are metacognition and SRL relevant to building adaptive learning systems like ITSs?

What is metacognition and self-regulated learning?

- Most ITSs and adaptive learning systems are limited to scaffold one aspect of learning: *cognition*
- Yet, human learning is a dynamic and complex combination of:
 - Cognition, emotions, motivation, metacognition
 - Environment
 - Time
 - Individual characteristics (personality, beliefs, values, race, gender, sex, background, experiences, and so on and so forth)
- ... that continuously evolve over time and contexts (domains, settings, etc.)

What is metacognition and self-regulated learning?

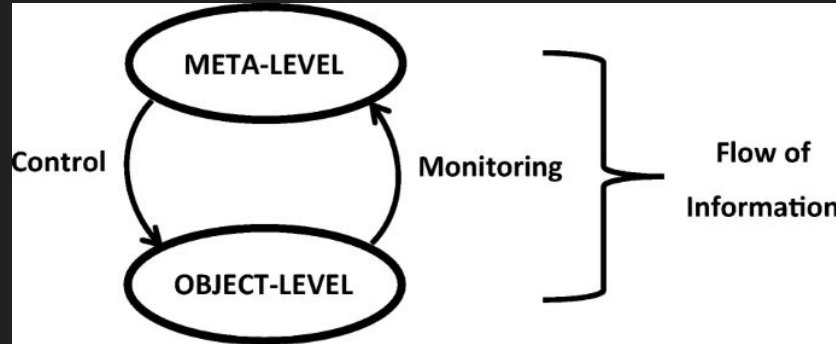
Cont'd...

Main ideas:

- SRL involves continuously **monitoring and controlling learning processes** (e.g., motivation, emotions, cognition) in pursuit of learning goals (Winne, 2018; Pintrich, 2004; Wigfield, Klauda, & Cambria, 2011)
- Metacognition is at the heart of SRL: Monitoring and controlling of cognitive processes
- SRL skills are a positive predictor of academic achievement, employability, and career progression (Schunk & Greene, 2018)

What is metacognition and self-regulated learning?

Cont'd...



Nelson and Naren's model of metamemory (1994)

Why does it matter that students demonstrate SRL skills?

- What are the benefits of having effective SRL skills?
- What is the goal of education and learning?
- How to solve societal problems when they are continuously changing and becoming more and more complex in the real-world?

How is it relevant for building ITSs and adaptive learning systems?

Current challenges in the field:

- Solely focusing on cognition misses critical information on students' learning
 - E.g., Motivation, emotions, and metacognition of which cognition could not occur without

Important open questions:

- How to build adaptive learning systems like ITSs to help students acquire adequate skills in SRL that transfer to real-world settings?

“Give a Person a Fish, and You Feed Them for a Day. Teach a Person To Fish, and You Feed Them for a Lifetime”

Comments? Questions?

ITSs, metacognition, and SRL today...

Help Tutor (Alevan et al., 2016)

- Help-seeking is a form of self-regulated learning, but students struggle to utilize help/hint features effectively with ITSs
 - Help abuse (e.g., gaming the system; Baker et al., 2004)
 - Help avoidance (Alevan et al., 2004)

Hypothesis:

Help tutor = students acquire skills in seeking and using help effectively that will transfer to other environments.

Help Tutor cont'd...

- Help Tutor that provide real-time feedback on help seeking during problem solving with the ITS
 1. Using model-tracing algorithm
 2. Principle-based hints
 3. Bottom-out hints - self-explanation

The screenshot shows a software window titled "Scenario" with a blue sidebar. The main content area displays a geometry problem involving an hourglass. The hourglass is represented by two vertical lines (segments AL and PI) intersecting at point R, forming two triangles: $\triangle ARP$ (top) and $\triangle IRL$ (bottom). The top of the hourglass is a blue oval. The hourglass is filled with orange sand.

Given: In the Hourglass shown, Segment AL intersects Segment PI at Point R.

A "Hint" dialog box is open, displaying the text: "A hint could be helpful, as this is likely a challenging step for you." Below the text are navigation buttons: "<<<", ">>>", and "OK".

Below the hourglass, the problem asks: "1. If the measure of Angle ARP = 41.1 degrees, find the measure of Angle IRL."

The user has entered the following values in a table:

m \angle ARP	41.1	Reason	Given
m \angle IRL	138.9	Reason	

Below this table, the second problem is visible: "2. If the measure of Angle IRL = 43 degrees, find the measure of Angle ARP." The user has entered values for this problem as well, though they are partially obscured.

The bottom of the window shows the label "Hourglass" and a vertical scrollbar on the right side.

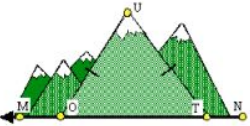
Help Tutor cont'd...

- Production-system Model: Rule-based model that collects adaptive and non-adaptive help-seeking actions
 1. Contextual features - conditions in which help was adaptive or non-adaptive
 2. Students' judgment on whether help was sufficient in problem solving
 3. 80 production rules - including a taxonomy of non-adaptive help-seeking behaviors categories: Help Abuse, Help Avoidance, Try-step Abuse, and more detailed sub-categories

Help Tutor cont'd...

Geometry Reason Tool

Given: The tallest mountain (Triangle OUT) in the Green Mountain range is an isosceles triangle.



scenario

skills

- Working with the equal angles in isosceles triangles
- Working with angles in a triangle
- Working with the non-equal angle in isosceles triangles
- Working with the outside angle of a triangle
- Working with triangles having all equal angles

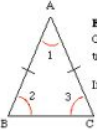
Solver

Glossary

Search for triangle
You see 7 out of 29 items

- Angle in Equilateral Triangle
- Converse of Isosceles Triangle
- Isosceles Right Triangle
- Isosceles Triangle**
- Right Triangle Complementary Angles
- Triangle Exterior Angle

If two sides of a triangle are congruent, then the angles opposite these sides (the base angles) are congruent.



Example
Given: $\triangle ABC$ is an isosceles triangle, with $AB \cong AC$.
If $m\angle 2 = 52^\circ$, then $m\angle 3 = 52^\circ$.

1. If it rises from the base of Angle MOU to the top of Angle UOT, then the angles are:

m.:MOU	Reason	Given
102.5	Reason	Linear Pair
m.:UOT	Reason	
m.:OTU	Reason	
m.:OUT	Reason	


Hint

Angle OUT is a vertex angle in isosceles triangle OUT.

The other two angles in this triangle are a pair of base angles. Therefore, they are equal in measure. The sum of the measures of these three angles equals 180 degrees.

Can you now find angle OUT?

102.5 77.5



Send Show All

Help Tutor cont'd...

Sample hint sequence of the Geometry Cognitive Tutor

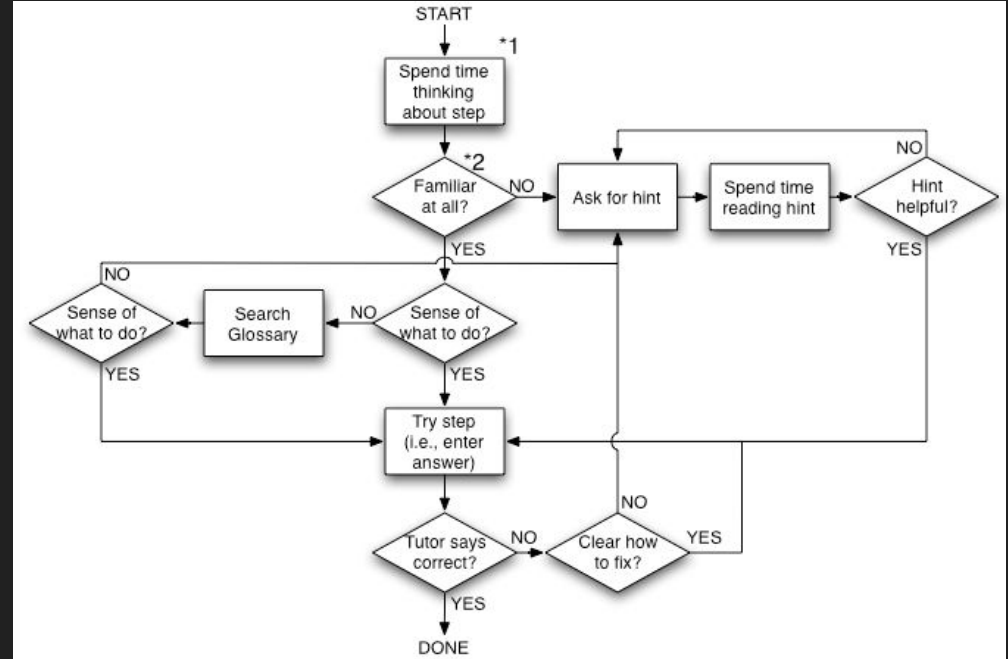
1. As you can see in the diagram, Angles UOT and MOU are adjacent angles. Together they form segment MT. How can you use this fact to find the measure of Angle UOT?
2. Look in the Glossary for reasons dealing with adjacent angles.
3. Some rules dealing with adjacent angles are highlighted in the Glossary. Which of these reasons is appropriate? You can click on each reason in the Glossary to find out more.
4. The sum of the measures of a linear pair of angles is 180° . Angle UOT and Angle MOU form a linear pair.
5. The sum of the measures of angles UOT and MOU is equal to 180 degrees.
6. The measure of Angle UOT is equal to 180 degrees minus the measure Angle MOU.
7. $m\angle UOT = 180^\circ - m\angle MOU$.

Help Tutor cont'd...

Example of production rules for defining help seeking behaviors (Aleven et al., 2006)

Help-seeking categories:

1. Help Abuse: help that avoids careful reading and sense making



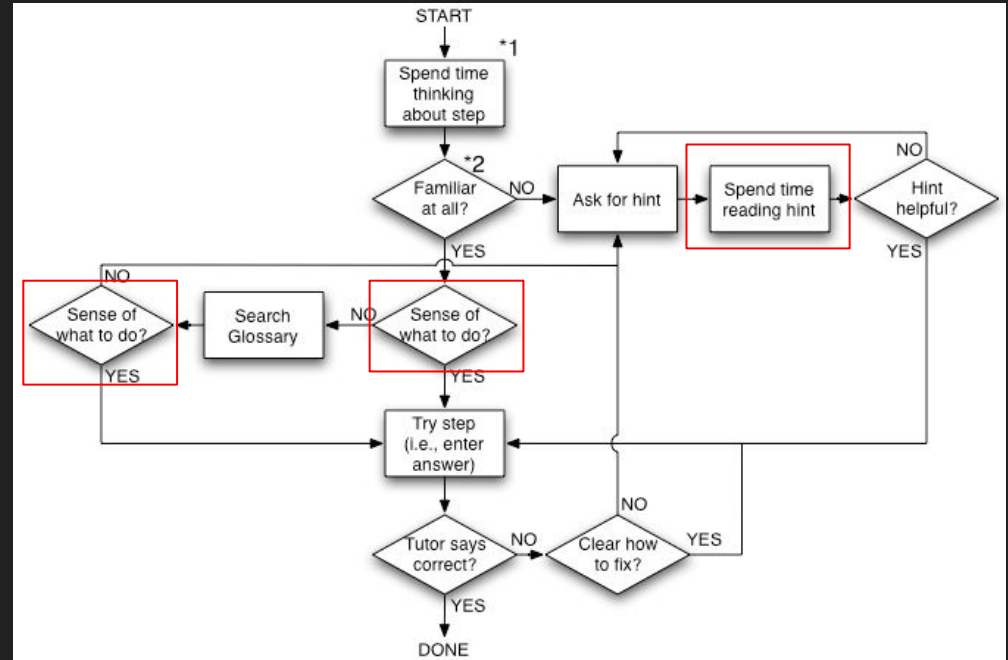
Help Tutor cont'd...

Example of production rules for defining help seeking behaviors (Aleven et al., 2006)

Help-seeking categories:

1. Help Abuse: help that avoids careful reading and sense making

Example: clicking through hints and spending little time reading hints



Help Tutor (Alevan et al., 2016)

- Help-seeking is a form of self-regulated learning, but students struggle to utilize help/hint features effectively with ITSs
 - Help abuse (e.g., gaming the system; Baker et al., 2004)
 - Help avoidance (Alevan et al., 2004)

Hypothesis:

Help tutor = students acquire skills in seeking and using help effectively that transfer to other environments.

Findings and Contributions

Results showing improved “local domain-level learning” and changes in how deliberately students use help, but no transfer to other domains or environments.

Beyond state-of-the-art for ITS research by

- Focusing on learning in context
- Taxonomy of maladaptive help seeking behaviors that were operationally linked to theoretical constructs (knowledge engineering)

Future Directions

1. Prioritize collecting data on sense making during the help-seeking process
 - Metacognitive monitoring?
 - What data might allow us to measure sense making?

Comments? Questions?

Scaffolding SRL with MetaTutor (Bouchet et al., 2016)

MetaTutor is built on production rules to scaffold SRL and teach students about biology (human circulatory system; Azevedo et al., 2022)

- Event- and time-based production rules that trigger tutoring agents to scaffold learners' SRL in real-time
 - Via tools on the interface
 - 4 pedagogical agents

Scaffolding SRL with MetaTutor Interface

MetaTutor (version 1.49.8)

Time Left
1:19:00

Learning Goal and Subgoals
Your goal is to learn all you can about the Circulatory System. Specifically, be sure to learn about all the different organs and other components of the circulatory system, and their purpose within the system, how they work both individually and together, and how they support the healthy functioning of the body.
Your current subgoals are
Blood vessels
Heart components

Table of Contents

- Introduction
- Components
 - Heart
 - Lungs
 - Lungs Cont.
 - Blood: Role
 - Parts of Blood Overview
 - Blood: Plasma
 - Blood: Red Blood Cells
 - Blood: Hemoglobin
 - Blood: White Blood Cell
 - Blood: Platelets
 - Blood Vessels
 - Vessels: Arteries
 - Vessels: Veins
 - Vessels: Capillaries
 - Blood Filtration
 - Heart
 - Cycle of Blood Flow
 - Anatomy and Structure
 - Cardiac Muscle
 - Heart Valves
 - Heart Beat
 - Heart Rate
 - Heart Rhythm
 - Diastole/Systole
 - Diastole/Systole Cont.
 - Development of the Heart
 - Systems of Circulation
 - Systems Overview
 - Systemic Circulation
 - Pulmonary Circulation
 - Other Aspects of CS
 - Hormones
 - Metabolism

Vessels: Capillaries [See Contents in Full View](#)

Blood Vessels: Capillaries

They are the smallest blood vessels in the body, only visible by microscope. The walls of capillaries are thin because they are the sites of oxygen and nutrient transfer for tissues. In fact, 10 capillaries lined up side by side are narrower than a human hair and if all the capillaries in the body were placed end to end, the total length would be approximately 46,325 kilometers (25,000 miles).

Although capillaries are the transitional areas from arteries to veins, capillaries do not return 100% of the blood from the arteries to veins. Some of the plasma will be pushed out of the capillaries by the pressure pushing blood through the circulatory system. This plasma will accumulate as interstitial fluid, which will return to the general circulation as lymph through a separate lymphatic circulation.

I would like to:
Plan my learning by...
Telling what I already know about this

Monitor my learning by...
Assessing how well I understand this
Evaluating how well I already know this content
Evaluating how well this content matches my current subgoal

Apply a learning strategy:
Take notes
Make an inference
Summarize

Take Survey Now

10:53 AM
1/28/2015

Scaffolding SRL with MetaTutor Interface Cont'd...

The screenshot displays the MetaTutor interface with several key components highlighted by red boxes and numbered 1 through 4:

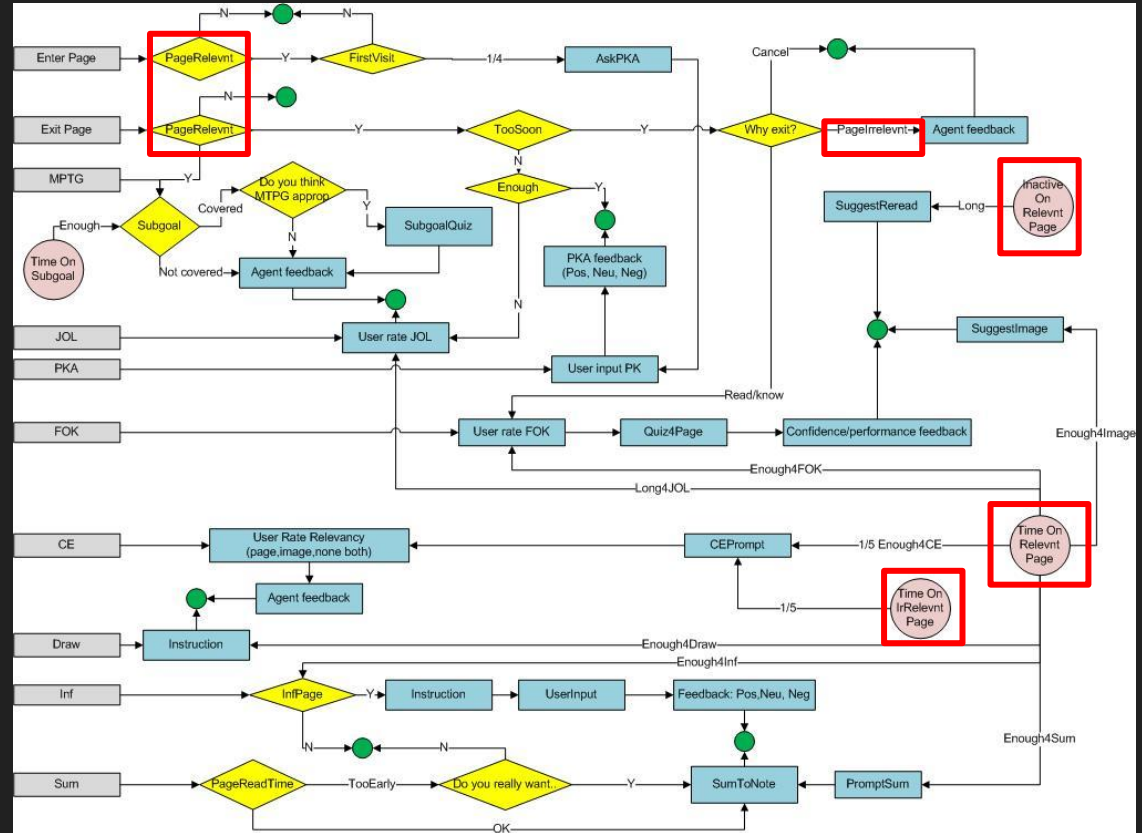
- 1:** The **Learning Goal and Subgoals** section at the top right, which includes the overall learning goal and a list of current subgoals (Blood vessels, Heart components).
- 2:** The **Time Left** indicator at the top left, showing 1:19:00.
- 3:** The **Table of Contents** on the left side, listing various topics such as Introduction, Components, Heart, and Systems of Circulation.
- 4:** The **Learning Strategy** panel on the right side, which includes options like 'Take notes', 'Make an inference', and 'Summarize'.

The main content area displays the **Blood Vessels: Capillaries** topic. It features a diagram of a capillary bed with labels for **Arteriole**, **Venule**, **capillaries**, and **Tissue cells**. The text explains that capillaries are the smallest blood vessels, visible only by microscope, and are the sites of oxygen and nutrient transfer. It also notes that although capillaries are transitional areas, they do not return 100% of the blood from the arteries to the veins.

Production Rules for Scaffolding SRL with MetaTutor

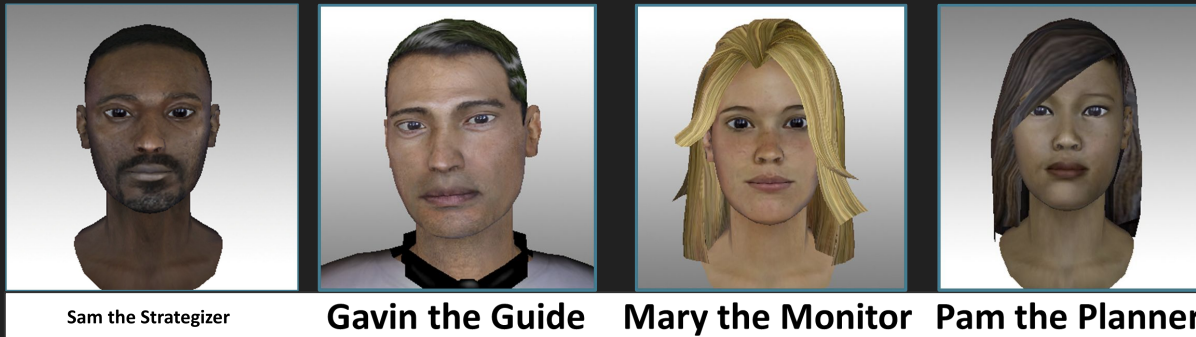
Data on SRL

1. Quantity - time and frequency of SRL processes via logfiles
2. Quality - time and frequency of visiting **relevant and irrelevant** pages based on subgoals set



Scaffolding SRL with MetaTutor Interface Cont'd...

- SRL palette used to prompt SRL use via pedagogical agents via production rules



I would like to:

Plan my learning by...

Telling what I already know about this

Monitor my learning by...

Assessing how well I understand this

Evaluating how well I already know this content

Evaluating how well this content matches my current subgoal

Apply a learning strategy:

Take notes

Make an inference

Summarize

Bouchet et al (2016) MetaTutor study

Examined 116 participants across three conditions designed to scaffold the quantity and quality of SRL via prompts:

1. Control (Non-adaptive prompting)
2. Fading prompts based on learners' SRL deployment
3. Increasing prompts based on learners' failed SRL deployment

Bouchet et al (2016) MetaTutor study

Overall findings:

1. Benefit of adaptive prompting on (self-)initiated SRL behaviors
2. Adaptive prompting did not lead to differences in learning between conditions

Conclusions and Future Directions

Limitations:

1. SRL processes deployed without using the SRL palette were missed
2. Data on all aspects of SRL were missed

Future directions:

1. How to design production rules and/or ITS interface to account for all aspects of SRL?
2. What data might provide insight into emotions and motivation?
3. What methods learned in previous lectures might be useful to this work?

Comments? Questions?

What are important things to consider when tutoring metacognition and SRL?

How do we “get it” right?

Is it a promising technology?

Is it widely used today? Mostly no.

But there is CSMLearn

<https://www.smilabs.org/solutions/individuals>

General Open Questions in the Field

What are we missing?

1. Immersion in real-world context?
2. Diversity aspects (populations, cultures, background, etc.)?
3. Motivation?
4. Emotions?

Comments? Questions?

References

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