

Ruffle&Riley: Towards the Automated Induction of Conversational Tutoring Systems

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PAPER OVERVIEW

New type of **automated** and **domain-independent** intelligent tutoring system

- Generates tutoring workflow *automatically* around existing content
- Enables *free-form* conversational tutoring in *learning-by-teaching* format
- Features two *LLM-based agents* with the roles of student and professor
- Uses *Expectation Misconception Tailoring* (EMT) to structure dialogs

INTELLIGENT TUTORING SYSTEMS

Learning software that provides **personalized** and **adaptive** instruction

- **Content development** is major obstacle to widespread adoption
 - > Authoring 1 hour of content takes experts 10s to 100s of hours
- Workflow is structured into two loops
 - *Outer Loop*: Learning activity sequencing
 - *Inner Loop*: Feedback and assistance during activity

SYSTEM EVALUATION

Online user study (N = 100) with 4 conditions:

- *Reading*: Receives lesson text (same in all conditions)
- *Teacher Q/A*: Simple chatbot with Human written questions/answers
 - Feedback: Correctness of user response + Sample solution
- *LLM Q/A*: Simple chatbot with GPT-4 generated questions/answers
- *Ruffle&Riley*: Full system (EMT + Learning-by-Teaching)

Multiple-choice Post-test

Conditions	# of participants		Previous Knowledge	Learning Performance	
	Before filtering 100	After filtering 58		Post-test Scores (i.e., Multiple-Choice Questions)	
Reading	30	15	2.53 ± 0.41	5.07 ± 0.33	
Teacher Q/A	17	7	3.0 ± 0.58	4.14 ± 0.83	
LLM Q/A	23	15	2.2 ± 0.3	4.67 ± 0.35	
Ruffle & Riley	30	21	2.67 ± 0.43	5.19 ± 0.25	

Learning Experience Survey

Conditions	Learning Experience (1-strongly disagree, 7-strongly agree)						
	Engagement	Understanding	Remembering	Interruption	Coherence	Support	Enjoyment
Reading	4.33 ± 0.52	-	-	-	-	-	-
Teacher Q/A	5.0 ± 0.53	4.43 ± 0.65 ±	4.43 ± 0.65 ±	2.71 ± 0.64	5.43 ± 0.53	4.57 ± 0.57 ±	3.71 ± 0.52 ±
LLM Q/A	4.8 ± 0.47	4.4 ± 0.4 ±	4.33 ± 0.42 ±	2.67 ± 0.45	4.8 ± 0.43 ±	4.0 ± 0.44 ±	4.0 ± 0.44 ±
Ruffle & Riley	5.81 ± 0.3	5.81 ± 0.24	5.76 ± 0.22	2.19 ± 0.34	6.1 ± 0.21	5.9 ± 0.26	5.62 ± 0.31

USER INTERFACE

Free-form Dialog

Student Chat:

a

Nice to meet you, Teacher! I am Ruffle. Thank you so much for helping me study biology. I love to learn!

Hello! I'm eager to learn about cell biology. Could you please explain what the phrase "form follows function" means in this context?

The structure of cell components and organelles evolved to support their specialized functions.

Thank you for your explanation! So, "form follows function" in cell biology means the structure of cell components and organelles supports their specialized functions.

Could you provide an example to illustrate this concept?

type here

Professor:

Please help the student learn the material.

Organelles in Eukaryotic Cells

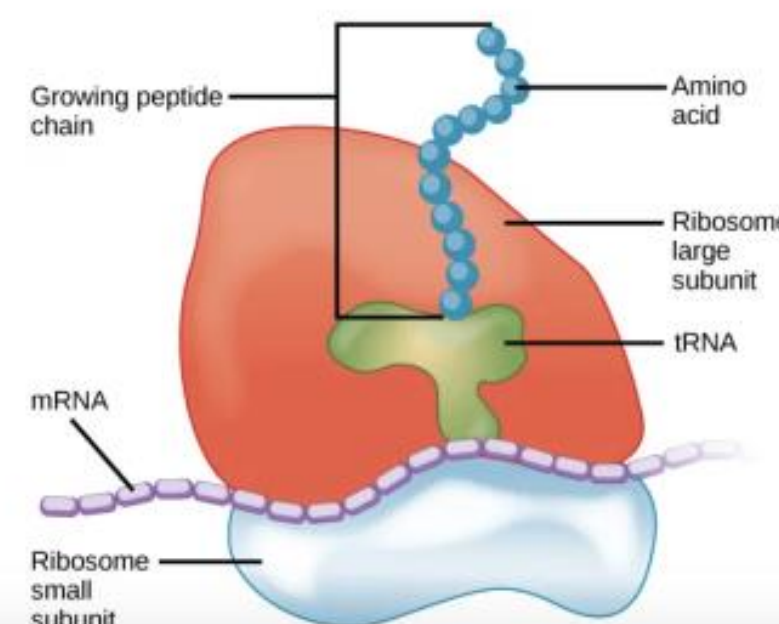
b

"Form follows function" is a philosophy that many industries follow. In architecture, this means that buildings should be constructed to support the activities housed within them. For example, a skyscraper should include several elevator banks. A hospital should have an easily accessible emergency room.

Our natural world also utilizes the principle of form following function, especially in cell biology. The structure of cell components and organelles evolved to support their specialized functions. For example, in the pancreas there are cells that are responsible for producing digestive enzymes, which are specific types of proteins that help with food digestion. In these cells, ribosomes, the organelle responsible for protein synthesis, are found in high numbers. Here the form (high number of ribosomes) follows the function (protein production). Apart from ribosomes, cells have numerous other organelles. These organelles are specialized compartments inside the cells, and similar to the organs in your body, each organelle has a unique role. In this lesson, we will dive into several examples of organelles and discuss their specific functions.

Ribosomes

Ribosomes are the cellular structures responsible for protein synthesis. They may group together into clusters (polyribosomes) or individual ribosomes may float freely in the cytoplasm. They may be attached to the plasma membrane's cytoplasmic side or the endoplasmic reticulum's cytoplasmic side and the nuclear envelope's outer membrane. Ribosomes are large protein and RNA complexes, each consisting of two subunits, one large and one small (Figure 1). Ribosomes receive their "orders" for protein synthesis from the nucleus where the DNA transcribes into messenger RNA (mRNA). After transcription, the mRNA exits the nucleus and travels to the ribosomes located in the cytoplasm. The ribosomes then translate the code provided by the sequence of the nitrogenous bases in the mRNA into a specific order of amino acids linked together to form proteins. Amino acids are the building blocks of proteins.



Source material: OpenStax, Biology 2e

Pre-existing Textbook Content

Intelligent Feedback

c

I don't know.

No worries at all! If you could request help from the professor, that would be fantastic. I'm really interested in understanding this concept better with an example.

On Demand Assistance

d

Professor:

Of course! You could use the example of ribosomes in the pancreas cells. These cells have a high number of ribosomes because they are responsible for producing digestive enzymes, a type of protein. Here, the form (high number of ribosomes) follows the function (protein production).

Misconception Correction

e

Enzymes that are produced by mitochondria

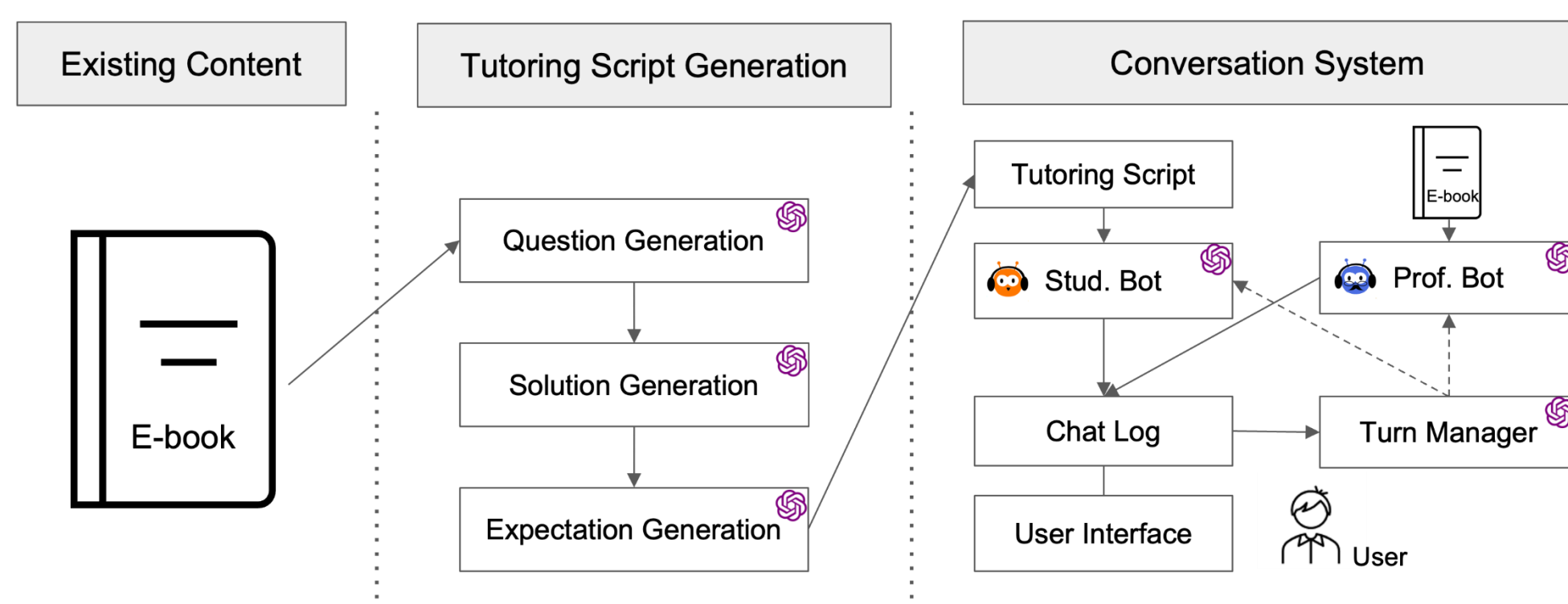
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Professor:

It seems there's a small mistake in your response. Mitochondria are actually responsible for producing ATP, not enzymes. Could you please revise your response?

SYSTEM ARCHITECTURE

Employ GPT-4 for tutoring **script generation** and **orchestration**



Learning-by-teaching workflow:

Student agent: Asks user to teach the material; Guides conversation to cover all questions and expectations in the tutoring script

Professor agent: Provides feedback on user's teaching; Provides hints in response to help requests; Prompts user to correct incorrect explanations

FUTURE WORK

- Extend system evaluation
 - Evaluate learning outcomes with deep understanding questions
 - Evaluate effects on knowledge retention
- Refine learning workflow
 - Chatbot users focused on the question content
 - Let users review content before teaching student agent
- Add human-in-the-loop capabilities (e.g., to revise tutoring scripts)
- Perform in-depth evaluation of conversation properties
 - How does explanation quality relate to post-test performance?
 - Are there questions or parts of the lesson text that cause confusion?



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