

Boosting Metacognition via Metacognitive Wrapper

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ABSTRACT

UPDATED—29 April 2018. Metacognition is often described as thinking about thinking and is tightly related to academic success and intelligence. Very specific techniques exist for metacognition to be put in practice and improved. This paper introduces a proof-of-concept system to promote metacognitive skills. Its main purpose is to make learners more effective.

Author Keywords

Metacognition; learning; self-regulated learning;

ACM Classification Keywords

Applied Computing---Education---Interactive learning environments; 500

INTRODUCTION AND MOTIVATION

General Information

Metacognition is often defined as “thinking about ones thinking”. It is a process to plan, monitor and assess what one knows, what process one follows when learning and what difficulties one encounters while learning and why [7].

Metacognitive skills have proved to increase learning outcomes. This makes them essential for everyone that needs to learn. They are a subcomponent of a broader skill set called self-regulated learning (SRL). SRL is learning where students adapt their approaches to it [17]. While SLR may not always be metacognitive, the capability to reflect on the cognitive strategies used and evaluate them is metacognition.

The benefits of SLR and metacognition have been well studied during the years. SLR is a key for problem-solving, academic success and transfer of knowledge [17]. Metacognition has been proved to increase academic success [7], help learners transfer their learning to different tasks thus adapting better to new contexts [6] and become aware of their strengths and weaknesses. Metacognitive

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knowledge has also been related to the failure of recognizing incompetence [9] also known as the Dunning-Kruger effect - a theory stating that failure to produce correct answers guarantees the inability to recognize if an answer is correct or wrong.

Metacognition has two dimensions: metacognitive knowledge and metacognitive regulation. The first one relates to what one knows for a particular task, their learning abilities and different techniques of learning. The second one relates to the ability to monitor and control the process of learning: what works, what does not and why.

Improving Metacognition

In order to improve metacognitive skills, both dimensions need to be addressed. In classroom settings, metacognition can be improved in four ways: promoting general awareness, improving knowledge of cognition, improving regulation of cognition and fostering conducive environments [13].

General awareness is making a clear distinction between cognition and metacognition, sharing thoughts about the metacognitive process learners follow among them. A way to improving knowledge of cognition is learners to review a strategy matrix where different techniques are described along with their usage. Regulation can be improved using a regulatory checklist including questions in 3 categories: planning, monitoring and evaluating. Fostering conducive environments can be achieved through promoting a specific goal orientation.

Other studies [15] suggest using assignments for explicit instruction including the following phases: preassessments – what prior knowledge the student has on the topic; difficulties – what is hard to learn; retrospective postassessments – what has changed in the knowledge on the topic; reflective journals – what has worked well this time, what has not and what can be improved.

Technology can help students self-regulate their learning but very little is known about how to do it effectively [14]. A number of experiments have been conducted using online environments and technological tools. It has been proven that metacognitive prompts in online learning environments are an effective mean for improving learning outcomes [4]. Computer-based learning environments (CBLEs) are capable of supporting the use of different tools for different tasks which effectively makes them adaptive to the learner needs [8]. An example of this is the controlled trial with Rosendale Primary School where Evernote was delivered to

support note-taking, video recording and linking, image taking and so on [11]. Traditional CBLEs represented by intelligent tutoring systems (ITSs) have been very successful when it comes to scaffolding student's learning of well-structured tasks like algebra, based on the ability to dynamically and systematically adapt, monitor and scaffold learner's individual learning [1].

Related Research

Similar research has mainly been done in Carnegie Melon, Columbia University and Western Kentucky University. Several similar projects have been identified.

PIM

The first of them describes PIM – Personal Intelligent Mentor[5]. It is an intelligent agent that helps students practice thinking logically and developing problem-solving strategies in the process of solving logic word puzzles. Its features include serving as a pedagogical expert, evaluating student's reasoning, assessing progress, promoting reflection and mindfulness, demonstrating mastery, visually assisting with problem-solving, providing flexible feedback. The authors point out that a critical issue is the moderation between the agent and the student – the thinking should be done by student and be assisted by the agent and not vice versa. The paper presents theoretical foundation for a future development of a software system.

gStudy

Another paper describes gStudy software. It is a shell that allows learners to study a learning kit about any topic presented in various ways: text, video, audio, image and so on [16]. It provides cognitive tools that allow learners to engage with multimedia presentation in numerous ways: annotate, analyze, classify, organize, cross-reference and index it. A built-in chat tool supports conversational stems to highlight different functions they serve according to a predefined scaffold. A log analyzer is another major feature of the software [18]. What is remarkable about the project is that it opens the door for research based on the captured collaboration.

Help Tutor

The Help Tutor add-on for Cognitive Tools is a metacognitive tutor to teach help seeking [12]. Authors state a key point: not every system that supports metacognition also teaches it. As a result, they describe a set of guidelines on which Cognitive Tutors are based – a widely adopted Intelligent Tutoring System (ITS):

- represent student competence as a production set;
- set explicit declarative, procedural, and dispositional learning goals of the desired metacognitive skill;
- promote an abstract understanding of the problem-solving knowledge;
- provide immediate feedback on errors;

- support metacognition before, during, and after the problem-solving process;
- minimize working memory load;
- communicate the goal structure underlying the problem solving;
- communicate the metacognitive learning goals;
- attach a price tag to metacognitive errors;
- assess metacognitive knowledge and application directly.

The authors recognize that the principles are only studied in the context of Help Tutor and might not be directly applicable in other ITS.

MetaTutor

MetaTutor is another tool that appeared in literature. It is a hypermedia learning environment that is designed to detect, model, trace, and foster students' self-regulated learning about human body systems such as the circulatory, digestive, and nervous systems [2]. Working with it includes several stages: modeling of key SRL processes, assessing usage of these processes, a task where learners have to identify a SRL process that someone else is doing, and finally the actual learning environment. While the discussion is based on a monitored tutoring, the goal of the tool is to examine the effectiveness of animated pedagogical agents as external regulatory agents. The authors recognize the challenges of providing feedback both on the accuracy of the content and the appropriateness of the SRL strategies used by a student.

Reflective Assistant

This is an implementation of Claudia Gama's Reflective Assistant for Open EdX environment. It provides instructors with the capability to integrate metacognitive assessment in coursework [10]. The authors point out challenges both with the EdX platform and with the tools used.

SQ3R

SQ3R is an AI agent that turns a passive self-learning experience into an active one. The agent guides the student through a process of "Survey", "Query", "Read", "Recite" and "Review" cycle with the purpose to emulate a teacher-led content [3]. As an interesting observation is pointed that such setup is less of a back and forth conversation but more of a set process with a rigid flow. The author points out several suggestions about improvements among which the "Question Generator" service stands out. Its purpose is to help the learner define questions if they have a hard time doing it.

Motivation

Although similar works exist, each of them has its own limitations. The aim of the currently proposed tool is to be platform-independent environment that turns every web page into a learning resource and promote metacognitive skills using current metacognitive practices. I.e. it promotes

general awareness of metacognition, improves knowledge of cognition and improves regulation of cognition using pre and postassessments, feedback for difficulties and reflective journal.

METACOGNITIVE WRAPPER

Terms

Metacognitive Wrapper is the name of the tools presented in this paper. Later it is also referred as “the tool”, “the system”.

Web pages used as learning resources are also referred as “learning material”, “study material” and “learning resource”.

Strategy matrix can also be referred as “personal strategy matrix”, “matrix”, “library”, “personal library” and “personal strategy library”.

Technology Stack

Metacognitive wrapper is implemented as a web-based application deployed in Microsoft Azure. It is based on Microsoft .NET Framework 4.7.1, Microsoft ASP Net Core and C# is the language used for the back-end; react.js, HTML and CSS are used for the front-end; for implementing the storage it relies on Azure SQL DB. For text processing Microsoft Text Analytics is used.

Workflow and User Interface

When first started, Metacognitive Wrapper asks the user to register or login. Once logged in, the user is provided with several options: to start the main workflow and study a material, to review their personal strategy matrix or to read the FAQ of the tool.

The FAQ of the tool is just a list of questions with their answers. They contain not only information on how to use the tool, but also promote general metacognitive awareness: answered are general questions like what is metacognition and how is it different from metacognition.

Frequently Asked Questions

What is Metacognition?

Metacognition can be explained as “thinking about ones thinking”. It is a process to plan, monitor and assess what one knows, what process is followed and what difficulties are encountered while learning and why.

How is it different from Cognition?

Metacognition is tightly related to Cognition and they often overlap. One good description is given by Flavell: “Asking yourself questions about the chapter might function either to improve your knowledge (a cognitive function) or to monitor it (a metacognitive function).”

What are some benefits of Metacognition?

- It helps become an independent learner.

Figure 1. FAQ page.

The Library presents the personal strategy matrix. Each new account receives four strategies as defined by Schraw in their personal strategy matrix. The purpose of the Library is to be a quick reference for why, when and how to use a

particular strategy. It can further be extended with strategies that have proved efficient while learning using the tool.

| Name | How to Use | When to Use | Why to Use |
|--------------------|---|---|--|
| Skim | Search for headings, highlighted words, previews, summaries | Prior to reading an extended text | Provides conceptual overview, helps to focus one’s attention |
| Slow down | Stop, read, and think about information | When information seems especially important | Enhances focus of one’s attention |
| Mental integration | Relate main ideas. Use these to construct a theme or conclusion | When learning complex information or a deeper understanding is needed | Reduces memory load. Promotes deeper level of understanding. |
| Diagrams | Identify main ideas, connect them, list supporting details under main ideas, connect supporting details | When there is a lot of interrelated factual info | Helps identify main ideas, organize them into categories. Reduces memory load. |

Table 1. Out-of-the box strategies in users’ personal libraries as defined by Schraw in 1998.

The main workflow starts with entering the URL (unified resource locator) address of a web page where the target learning resource is. Upon entering it, the content is extracted and loaded into the system.

Metacognitive wrapper

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Figure 2. Entering the learning resource's url address.

Next, the tool detects keywords from the text extracted. The user is asked to leave only those which are really relevant and remove those they feel are irrelevant.

Please, remove any keywords that are not important or relevant:

- conditional knowledge
- procedural knowledge
- declarative knowledge
- types of metacognitive knowledge
- regulation of cognition
- important form of metacognition

Select

Figure 3. Detected keywords.

The user is then asked specific questions based upon the keywords and general questions about the topic so that preassessment can be made: what is the expected outcome of the learning; what the user knows for each keyword prior to reading the material; what the differences between two different keywords are and what the similarities are. The answers to those questions are stored for later reference.

Please, take a moment and answer the following questions:

- What do you expect to get out of this learning material?
I hope to learn how to successfully apply metacognitive techniques.
- What do you think of conditional knowledge
I am not familiar with conditional knowledge.

Done

Figure 4. Questions based on the detected keywords.

After the questions are answered, the learning can begin. As soon as the user approaches half of the material, the system again takes action. It requires the user to think about their progress and to rate it. If the rating is not satisfactory (less than 5 out of 5), then the user is again asked to describe the difficulties they experience during learning. They are also presented with the option to review the personal strategy matrix. After reviewing, the only option to continue is start reading the article from the beginning.

Please, rate your progress so far:



Figure 5. Rating progress.

Home FAQ Library Hello anenkov3@gatech.edu Log out

Metacognitive wrapper

Scroll down

Here is a list of strategies you may find useful:

| Strategy | How to Use | When to Use | Why to Use |
|-----------|---|---|--|
| Skim | Search for headings, highlighted words, previews, summaries | Prior to reading an extended text | Provides conceptual overview, helps to focus one's attention |
| Slow down | Stop, read, and think about information | When information seems especially important | Enhances focus of one's attention |

Done

- Learning styles
- Metacomprehension
- Mindstream
- Mirror test
- Second-order cybernetics

Figure 6. Strategy Review.

Again, after reaching half of the material, the user is asked to rate their progress. After selecting a passing rating (5 stars) the user is allowed to continue reading the material.

When the end is reached, the system again asks the very same questions it has asked in the beginning. This is done to enforce reflection on what has been learned. After answering it shows the old answers along with the new ones so that the user can evaluate what has been learnt.

You can see how your knowledge has evolved:

- What do you expect to get out of this learning material?
I hope to learn how to successfully apply metacognitive techniques.
- What do you think of conditional knowledge
I have learnt about various Metacognitive techniques and how to successfully apply them when learning.
- What do you think of conditional knowledge
I am not familiar with conditional knowledge.

Done

Figure 7. Showing how knowledge has evolved after reading the learning material.

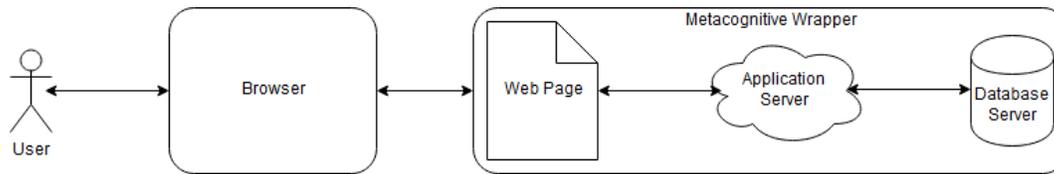


Figure 8. High-level architecture of Metacognitive Wrapper

Finally, the user is presented with the option to add any strategies that have worked during learning to the personal library.

Architecture

The tool is built as a 3-tier application. The client in the form of a browser makes requests using react.js JavaScript library. The server is an API that responds to the requests with the data that should be appropriately rendered in the browser. The data itself is taken from a database (DB) server.

The application is deployed in the cloud on Microsoft Azure. This gives several advantages among which it worth mentioning the ease of scaling, ease of deployment and the ease of integration with all other Microsoft services and tools available in the platform.

Two key implementations details have to be noted. First one is that Microsoft Text Analytics API is used to provide insights from the article's text. Precisely, it is used for keyword extraction. The ease of integration and the quality of the results were the primary reasons for choosing that particular API.

The second detail is related to the front-end implementation. The system uses an iframe HTML element to load third party web pages. There are limited possibilities to load external web pages and each one has its own restrictions. This particular approach brings security problems as many web site creators and administrators prohibit loading their pages in such a way. The approach to overcome this was to get the content in the back-end, simulating that a client requests the external resource. The retrieved content is then sent to the client for the browser to render. However, the rendered content contains links to other external resources like styles, fonts and images which bring the same problem again. This secondary problem was not addressed and as a result, learning resources usually do not look like their original versions.

Limitations

Currently the application has several limitations.

Among all, the most important one is that some pages might not load correctly. Although the application relies on the server to request external resources and return them to the client, if the authors have disabled Cross-origin resource sharing (CORS) then resources on which the page itself depends like external styles, fonts and images may not be correctly loaded.

Another limitation is related to the length of the articles. As the tool depends on 3rd party application like Microsoft Text

Analytics, same limitations apply for it as well. The maximum article length is limited to 5 000 000 characters.

English is the only supported language. However, the tool can easily be adapted to support more languages.

Further Work

Certainly, there is a lot more that can be done to make the tool more valuable.

The most important feature that was left out of scope was the possibility to share the strategy matrix among learners as well as their thoughts on metacognition. It can automatically detect what strategies have worked for others when they had encountered similar difficulties when learning and suggest them to the user.

Another option is to suggest other learning resources on the same topic, addressing specific parts of it that the user has found to be difficult.

A next-to-do item is evaluating the effectiveness of the tool. Various approaches might be taken to achieve that but this will give a solid ground for putting efforts in further development.

CONCLUSION

Metacognitive skills are proved to be a basis for better learning. Being aware that they are important, knowing how to use different strategies to boost them and taking time to think over the processes we follow internally are making us more efficient learners.

The proposed tool helps individuals, to increase their learning outcomes, putting proven metacognitive strategies into practice.

A working version of the tool can be found at <http://metacognitivewrapper.azurewebsites.net/>

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