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Generative AI and Metacognition

Using AI to help learners become better learners

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September 2023

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Learnovate Report

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Executive Summary

This report explores how Generative AI (GenAI) could be used to foster learner metacognition, which is the ability to reflect upon and regulate one's own thinking. From a learning perspective, metacognition is a powerful tool since research has consistently shown that developing metacognitive learning skills makes learning more effective and efficient while also improving learning outcomes.

Concretely, metacognitive learning skills are composed of, on the one hand, the learner's self-awareness of how they learn and, on the other hand, strategies and techniques the learner uses to undertake learning activities.
This self-awareness involves planning, monitoring and evaluating one's learning while the strategies and techniques a learner can use to learn more effectively range from simply being able to summarise content to more complex problem-solving strategies.

GenAI opens up a number of opportunities for supporting learners in their development of metacognitive learning skills:

- mentoring: where GenAI could be used to guide the learner and help them foster their metacognitive skills
- personalisation: where GenAI could be used to deliver highly tailored learning content that incorporates metacognitive development
- learning nudges: where GenAI uses data about the learner to provide small nuggets of advice on their learning strategy
- assessments: where GenAI could create tailored assessments that not only test the learner's knowledge but also reinforce their metacognitive skills
- reflection: where GenAI could guide the learner through a deeper reflective process aimed at refining and improving their metacognitive skills

While GenAI continues to develop at breakneck speed and some of the above possibilities are already being explored, we need to be conscious of the potential dangers.
Notable amongst these are concerns over the privacy and security of data, doubts over the accuracy and reliability of GenAI and a growing digital divide between those who have access to the technology and those who don't.

It seems prudent to proceed with GenAI as a tool for learning - but with caution if we are to ensure the fostering of better learners and the delivery of improved learning outcomes.

What is Metacognition?

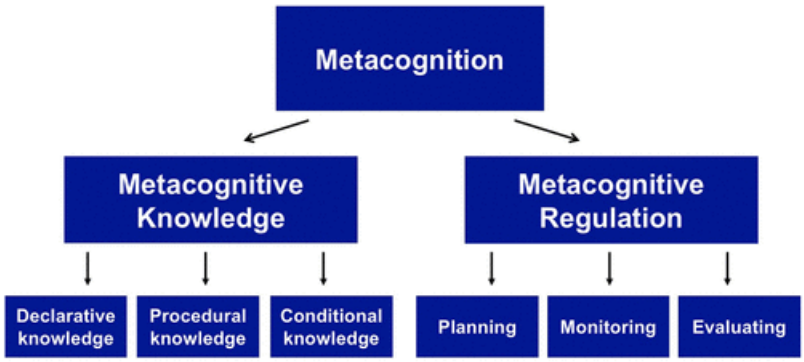
Metacognition can be defined as the 'awareness or analysis of one's own learning or thinking processes'[1]. To put it another way, it is the ability to reflect upon and regulate one's own thinking.

The psychologist John Flavell originally developed the concept in the late 1970s when he was researching 'cognitive phenomena' around learning. Flavell emphasised the importance of self-knowledge in metacognition - that is, the learner's awareness of their own strengths and weaknesses. Adding weight to this notion, it has been argued that one of the hallmarks of an expert is that they know when they don't know something and can rely on a strategy to overcome their lack of understanding[2].

In the last forty years, a large body of evidence has emerged showing that improved metacognitive abilities lead to raised academic levels. The research indicates that learners learn more when their metacognitive skills are well developed and these findings occur with surprising regularity and consistently across multiple types of learning contexts and materials.

Metacognition is made up of two distinct components: metacognitive knowledge and metacognitive regulation[3]:

- ***Metacognitive Knowledge*** **-** this refers to the learner's understanding of metacognition.
- ***Metacognitive Regulation*** **-** this refers to the learner's ability to apply (and refine) their metacognitive knowledge.



In the above model, Metacognitive Knowledge is broken down into the following sub-components:

[1] https://www.merriam-webster.com/dictionary/metacognition
[2] https://doi.org/10.1207/s15430421tip4104_3
[3] https://www.lifescied.org/doi/10.1187/cbe.20-12-0289

- *Declarative knowledge* refers to what the learner understands about themselves as a learner, what a particular learning task might entail, and what strategies exist to help with that task.
- *Procedural knowledge* refers to knowing how to use learning strategies
- Conditional knowledge refers to knowing when and why to use particular learning strategies

Similarly, Metacognitive Regulation is broken down into the following sub-components:

- Planning refers to deciding what learning strategies to use and at what moment
- Monitoring refers to assessing the effectiveness of particular strategies while learning
- Evaluating refers to reflecting on the effectiveness of your overall learning plan and adjusting it as required for future learning

The Role of Metacognition in Learning

Metacognition is an important concept because 'the consistent finding in over 30 years of research is that more-successful students exhibit higher levels of metacognitive knowledge about a given domain and are more skilled at regulating their cognitive processes than less-successful students'[4].
Learners who have well-developed metacognition can identify concepts they don't understand and select appropriate strategies that will help them learn these concepts.
Metacognition allows the learner to become more expert-like in their thinking and, thus, more effective in their learning. Furthermore, when working in small groups, learners can stimulate metacognition in each other thereby adding a further layer to their metacognitive understanding.

Central to the role of Metacognition in learning is the learner's awareness of their own learning abilities - this can be as simple as realising that they don't know much about a particular topic and paying closer attention. In addition, by being aware of metacognitive strategies, the learner can apply different techniques to enhance learning - such as for memorising important details about a topic. Similarly, if a learner realises they already know a lot about a topic in a textbook, they may adjust their reading approach or rate.
Other examples of metacognitive strategies include setting learning goals and subgoals, the learner asking themselves questions as they read a piece of text, or re-reading something they don't understand.

[4] https://www.sciencedirect.com/topics/medicine-and-dentistry/metacognition

It should be noted that activities aimed at fostering metacognitive skills can be embedded in the learning activity design (e.g. solving a problem), explicitly as a separate activity (e.g. writing a reflection), or a combination of both.

Metacognition and Collaborative Learning

The renowned psychologist Vygotsky theorized that the capacity for cognitive and meta-skills during the learning process is developed during the learner's interaction with more able peers or the teacher within the learner's Zone of Proximal Development (ZPD). Vygotsky explained this principle very simply: "What a child can do in cooperation today, he can do alone tomorrow".

Building on Vygotsky's work and other learning theories, researchers have begun exploring the relatively new field of inquiry called social metacognition. While individual metacognition involves awareness and management of one's own thinking, social metacognition involves the awareness of others' thinking. It is an important concept for supporting effective learning during collaborative activities - particularly from certain subjects such as the sciences. Social metacognition can be facilitated when learners share and evaluate each other's ideas allowing them to see different strategies for approaching particular activity.
The importance of collaborative learning means that it should be incorporated into any solution where GenAI is used to foster Metacognition.

GenAI, Learning and Metacognition

Metacognitive skills will become more important when using AI because, in the future, humans will be focusing on more novel and poorly defined problems.
Metacognitive skills are not innate or fixed, but can be learned and improved with practice and guidance - and GenAI could play a significant role in this process.
Fostering learner awareness of the concept of metacognition is a key 'first step' in helping learners build their own learning skills and acquire a deeper understanding of how they learn.
If GenAI is to be leveraged as a tool to foster metacognitive learning skills, it must be able to address the core key skills of metacognition, namely:

- the ability of the learner to identify concepts they do not understand and select appropriate strategies for learning those concepts
- the ability of the learner to implement strategies they have selected and carry out their overall study plans
- the ability of the learner to evaluate their strategies and adjust their plans based on outcomes.

- the ability of the learner to be more expert-like in their thinking and more effective and efficient in their learning
- the ability of the learner to collaborate in small groups stimulating metacognition in one another and leading to improved outcomes

It has been argued that GenAI has the potential to bring about a paradigm shift in educational programs through the enhancement of learners' metacognitive capacities as well as both personalised content and learning experiences[5].
Examples of how GenAI could be used as a tool for fostering learner metacognition include:

- Constrained Choice Exercises that limit the scope of the learner's inquiry with the aim of fostering higher-order thinking.
- Reflection Activities that encourage the learner to think about their learning. This could take the form of questions such as asking the learner what learning strategies and skills proved effective for a task or what action they should take next.

GenAI could be used to make learners' thinking more apparent to themselves, their learning peers, and their tutors. It can do this, for example, by presenting case studies or 'worked examples' and asking the learner to explain their thoughts on the material. It can also do this by providing adaptive, tailored feedback and support that helps learners carefully build knowledge and skills. More specifically, this can take the form of tailored assessments and it has been argued that GenAI is seeing the emergence of a new formative assessment model called 'Metacognitive Continuous Learning' that helps the learner understand, monitor, and regulate their cognitive and metacognitive processes.[6] In this new model, GenAI breaks down the distinction between learning and metacognitive learning since the assessment becomes an integral part of the learning process and the learning becomes an essential part of the assessment process.

Furthermore, GenAI could be used to encourage learners to reflect more deeply on what they've learned and how they've learned. This could be done in the form of a post-learning discussion between the learner and a GenAI chat-bot.

[5] https://digitalcommons.lindenwood.edu/faculty-research-papers/480/
[6] https://medium.com/@guylevi.57/transforming-education-in-the-generative-ai-era-4c7e177a8415

GenAI and the Tutor

GenAI could become a powerful tool to assist tutors and educators in a number of ways[7]:

- Data-driven insights: By collecting and analysing vast amounts of data on learner behaviour and interactions with learning materials, GenAI could provide valuable insights into their learning processes.
- Personalised Feedback: GenAI could provide immediate, personalised feedback to learners and propose activities that promote metacognitive skills.
- Cognitive Assistance: GenAI could engage in conversations with learners that help them articulate their thought process thus fostering metacognitive development.
- Visualisation Tools: By generating a visualisation of the learners cognitive processes, these could be rendered more tangible and understandable to the learner.

GenAI could also assist with delivering differentiated learning that currently requires the tutor to adapt the learning material to manage different rates of student progression. GenAI could be used to adjust the sequence and difficulty of the learning materials based on each learner's progress thus relieving the tutor of a difficult and onerous task and allowing them to focus on other activities.

Potential Downsides of Using GenAI

The use of GenAI as a tool is not without a number of potential downsides:

- Privacy and Security - the collection, use and storage of data by any GenAI solution needs to be subjected to rigorous control and oversight to ensure the confidence of users.
- Cost- building GenAI tools that can effectively deliver better learning experiences may prove too costly for some.
- Accessibility - using GenAI effectively requires a high level of technical expertise making it a challenge for those without the necessary digital skills.
- Explainability - any GenAI needs to be transparent in its interactions with learners to minimise the chances of bias or incorrect/inaccurate functioning.
- Reliability - any GenAI solutions need to be carefully monitored to insure they are producing content of an acceptable and reliable standard.
- Digital Poverty - As GenAI relies heavily on massive computing power which is much more readily available in developed countries, its widespread use could widen the digital divide.

[7] https://www.linkedin.com/pulse/supercharging-metacognition-ai-unveiling-secrets-black-stephanie-holt/

Furthermore, the drafting of legislation on the use of GenAI is lagging behind the rapid pace of development making regulation a significant challenge.

Consequently, any use of GenAI needs to be carefully monitored, controlled and subjected to independent verification.