Metacognition Tracker

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***Abstract*—Meta-cognition is defined most simply as “thinking about thinking.” Meta-cognition can be divided into two major components: knowledge and regulation. Meta-cognitive knowledge includes knowledge about oneself as a learner, and the factors that might impact performance, knowledge about strategies, and knowledge about when and why to use strategies. Meta-cognitive regulation is the monitoring of one’s cognition and includes planning activities, awareness of comprehension and task performance, and evaluation of the efficacy of monitoring processes and strategies. This project can measure one’s meta- cognitive ability which can be used for academic development and achievement. Our system will help educators to identify the learning strategies of each student and provide scaffolding to improve their performance. Based on our survey we have observed that there exist e-learning systems that help students to understand a topic/subject. But none of them measures the meta-cognitive level of students. Currently, Researchers use a subjective questionnaire to measure the meta-cognition level of a person. However, this questionnaire might give biased results. We are developing a web-based system that will help academicians to access the meta-cognition level of students. In the system, we are focusing on only oops concepts to keep area specialization and we will assess the meta-cognition level of students through their interaction with the system (log data). Based on students’ logged activities a comprehensive analytical report including all major components and subcomponents of meta-cognition will be generated. Our system will help educators to perform in-depth analysis based on the facts presented in the report and provide useful guidance to the students to improve their self-learning skills and decision-making.**

Keywords- Metacognition, Self-Regulated Learning, Knowledge and regulation, E-learning.

I. INTRODUCTION

- Current Scenario

In the past, the students used to get knowledge from teachers. However, it was observed that even though the same teacher was teaching to many students, there was a difference in the scores of students. Why was this happening? Because each student can’t have the same strategy to learn new things. So later a term was discovered called “Self-Regulated Learning (SRL)”. Many students started using SRL in their learning environment. But still, students were facing difficulties in facing appropriate strategies while doing SRL. After some more research, SRL divided into three components: - Motivation, Cognition, and Metacognition. The first 2 components are taken care of by the current education environment, but very few are aware of metacognition.

In today’s world, there are lots of e-learning systems and materials available on the internet that help students to understand a particular topic. There are various Intelligent Tutoring Systems also which helps students to learn based on their understanding level.

Our aim is not to help students to learn a topic. But to help them understand their own strategy, thinking process, and results for the same through Analytical report.

The report is based on various factors that we will discuss further.

- Need of the proposed system

Today, students are getting motivation from various sources: - Parents, teachers, social media, etc. Also, there are various E-learning systems, which provide students with better visualizations of any topic from the syllabus. There are various Intelligent Tutoring systems (ITS) also on the internet. This system creates a separate module for each student. And the model keeps continuously updated based on knowledge and activities performed by the students. These models help individual student, by suggesting the next topic they should learn (based on student’s past data). So both e-learning systems and ITS have made learning easy and interesting. But they are useful only from an academic point of view. That is students not focusing on making their own strategies and following the strategies suggested by the system.

We are developing a system where we will be generating analytical reports of students. Based on this on time scaffolding to students can be provided. And later based on the next analytical report we can also see what all new strategies are used by students. By doing this student learning on their own and planning their strategies (the system is not suggesting anything). This will help learners/students not only in learning something new but to take real-life decisions with high accuracy.

- Problem Statement

Self-Regulated Learning (SRL) is very essential to learn new things by yourself. SRL can be categorized into Cognition, Motivation, and Metacognition. Cognition and Motivation are being taken care of in the current education system, however, many people are still unaware of metacognition. Create a system that will help to measure one’s metacognition level. Metacognition includes knowledge about when and how to use particular strategies for learning.

- Scope of the Project

The Metacognition level of a student can be predicted using our system. Our system will help faculties to Identify the learning strategies of each student and provide on-time scaffolding to improve their performance. Developing metacognitive awareness is an important aspect in an educational scenario, it helps learners become aware of their own learning patterns. Metacognition ability plays a crucial role in self-regulated learning.

Appropriate counseling/scaffolding can be provided by the instructor to improve students’ metacognitive ability.

II. Related Work/Literature Review

Summary of the investigation in the published papers

Educational psychologists have long promoted the importance of metacognition in regulating and supporting student learning. However, educators may not be familiar with methods for teaching and assessing metacognition. MetaCognition is “thinking about thinking”. Metacognition is what enables a student who has been taught a particular strategy in a particular problem context to retrieve and deploy that strategy in a similar but new context. The authors note that in cognitive psychology, metacognition is often defined as a form of executive control involving monitoring and self-regulation, a point echoed by other researchers.

- Constituent Elements

Metacognition has two constituent parts: knowledge about cognition and monitoring of cognition. Several frameworks have been developed for categorizing types of knowledge about cognition. For example, several researchers have used the concepts of declarative and procedural knowledge to distinguish cognitive knowledge types. [1] Kuhn and Dean (2004) characterize declarative cognitive knowledge broadly as epistemological understanding, or the student’s understanding of thinking and knowing in general.
On the other hand, procedural knowledge involves awareness and management of cognition, including knowledge about strategies. [2] Schraw (2006) also distinguishes conditional cognitive knowledge, which is knowledge of why and when to use a given strategy. The other component of metacognition is the monitoring of one’s cognition, which many researchers have argued includes activities of planning, monitoring or regulating, and evaluating.
Researchers have observed a relationship between cognitive knowledge and cognitive monitoring. For example, [3] Flavell (1979) argues that metacognitive experiences that allow one to monitor and regulate one’s cognition play a major role in the development and refinement of metacognitive knowledge

- Development of Metacognition

Over Time Kuhn (2000) characterizes the development of metacognition as the very gradual (and not always unidirectional) movement to acquire better cognitive strategies to replace inefficient ones. Several researchers have concluded that metacognitive abilities appear to improve with age. [4] Schraw and Moshman (1995) posit that metacognitive development proceeds as follows: cognitive knowledge appears first, with children as young as age 6 able to reflect on the accuracy of their cognition, and consolidation of these skills typically evident by 8-10 years of age. The ability to regulate cognition appears next, with dramatic improvements in monitoring and regulation appearing by 10-14 years of age in the form of planning. Monitoring and evaluation of cognition are slower to develop and may remain incomplete in many adults. Finally, the construction of metacognitive theories appears last (if at all). These theories allow for the integration of cognitive knowledge and cognitive regulation.

- Specific Instructional Strategies

Researchers have recommended a number of specific instructional approaches to teaching metacognition. For example, many researchers have noted the importance of providing explicit instruction in both cognitive knowledge and cognitive regulation. [5] Cross and Paris (1988) recommend providing explicit instruction in declarative, procedural, and conditional knowledge. Similarly, [2] Schraw et al. (2006) and Schraw (1998) urge educators to provide explicit instruction in cognitive and metacognitive strategies. Further, Schraw emphasizes that such strategy training needs to emphasize how to use strategies, when to use them, and why they are beneficial. A number of other researchers echo the importance of highlighting the value of particular strategies in order to motivate students to use them strategically and independently.
Researchers also recommend the use of collaborative or cooperative learning structures for encouraging development of metacognitive skills. This recommendation appears to be rooted in Piagetian and Vygotskyian traditions that emphasize the value of social interactions for promoting cognitive development.

- Extant Assessment Methods

Given the complexity of the construct, many researchers have chosen to focus on only one or a few aspects of metacognition. Thus, measurement and assessment instruments designed to capture metacognition have typically focused somewhat narrowly on only a single dimension of the construct. Furthermore, because metacognition is not a skill that is traditionally assessed regularly in school as part of the normal curriculum, many of these assessments have come from experimental studies where the skills are practiced in a lab environment that is somewhat artificial or contrived, in the sense that it is not connected to school learning.
Researchers have often investigated young children’s theory of mind using location- false belief, contents-false belief, deceptive pointing, and appearance-reality tasks Each of these tasks involves cognitive conflict in some way, in the sense that successful performance requires subjects to suppress impulsive responses and to produce a response that is incompatible with the dominant response. For example, in one standard location-false belief task, a child observes two puppets interacting. One puppet places an object in a specific location and then “leaves the room.” The second puppet moves the object to another, hidden location. When the first puppet re-enters the room, the subject is asked to predict where he will look for the object—in the original location or in the new, actual location. Similarly, in a standard contents-false belief task, children are shown a common, brand-name box of bandages and asked to predict what is inside. The box is then opened and children are shown that it actually contains crayons. Another investigator then enters the room and is shown the closed box. Children are asked to speculate about what the second experimenter believes is in the box. Deceptive pointing involves a similar setup where students observe an object being hidden in various locations and are then asked to deceive a third person about the object’s location by “deceptively” pointing to a null location. Finally, a standard appearance-reality task attempts to train children to respond “day” when shown a picture of the moon and “night” when shown a picture of the sun.

Another common method for capturing metacognition is the use of self-report questionnaires or rating scales. [7] Kramarski and Mevarech (2003) used a metacognitive questionnaire, assessing both general metacognition and what they called domain-specific metacognition (math strategies). Students were presented with a range of strategies and asked to indicate whether and how often they used the strategies, employing a 5-point Likert scale that ranged from “never” to “always.” Cross and Paris (1988) assessed children’s metacognitive reading skills using two different measures. The Reading Awareness Interview was designed to 30 assess children’s awareness about reading in three areas: evaluation of task difficulty and one’s own abilities, planning to reach a goal, and monitoring progress towards the goal. The interview contained 33 Likert-scaled items and 19 open-ended questions. The authors also used a strategy rating task; strategies were read aloud and children were asked to rate the effectiveness of each on reading comprehension using a 7-point scale ranging from “hurts a lot” to “helps a lot.”

- General Suggestions for Assessing Metacognition

A few researchers have offered general suggestions for measuring or assessing metacognition. For example, Schraw and Moshman (1995) favor verbal report methods because they allow researchers to access aspects of thinking that are not directly observable. On the other hand, Whitebread etal. (2009) argue that observational methods have advantages over self-report and think-aloud methods. Observational approaches record actual learner behaviors, which enables nonverbal behaviors to be taken into account. Further, observational techniques can record social processes that may be important in the acquisition of metacognitive skills. Kramarski and Mevarech (2003) recommend using instructional tasks that are complex, allow multiple representations of concepts, and afford students opportunities to identify and resolve conceptual conflicts. Finally, Perry (1988) notes that writing activities, especially those involving students in all stages of the writing process (planning, drafting, editing, and revising) offer ample opportunities for self-regulated learning.

- Comparison between tools / methods / algorithm

Existing System	**Our System**
1. No software available to assess the metacognition level of a student.	1. Creating a web-based application to assess the metacognition level of a student.
2. Uses a generalized questionnaire to assess metacognition.	2. Using a domain-specific learning environment to assess metacognition.
3. Metacognition assessment is used on the basis of questionnaire results which can be biased.	3. Metacognition assessment is provided on the basis of various logs (revisits, quiz score, reattempts, time spent) captured by the system.
4. The results of the questionnaire can be biased.	4. The logs generated by the system can’t be biased.

II. Methodology

Methodology / Procedure Adopted

As we know that metacognition is a vast area in itself, and there does not exist any digital system in the market which can assess the metacognition level of students. So, we decided to minimize our problem scope by focusing on one topic "Object-Oriented Programming (OOPs)" and assess the metacognition level of students in that area. We decided to build a web-based system, which can be used by students to study various OOPs Concepts. Parallelly our system will be recording each and every activity performed by the user in the form of logs.

We know that the metacognition level of students can't be directly assessed based on just Quiz Score. So, we collect other data such as time spent, revisits, questions switching, etc. After getting periodic logs, we applied some algorithms to the data to generate the analytical report. This report is being made with respect to the "Metacognition Awareness Inventory" Questions. Teachers can use this Analytical report to assess the metacognition level of each student and provide on-time scaffolding.

III. Experiment and Analysis

System Architecture / Design

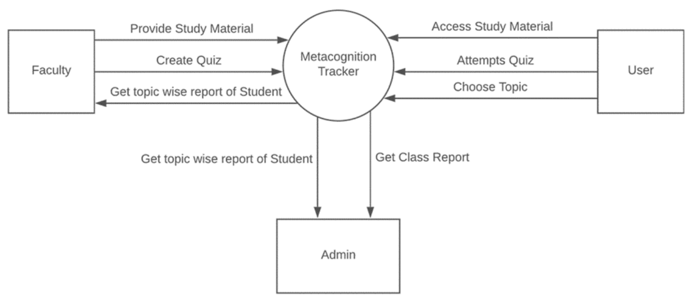

Fig. 1. DFD LEVEL 0

In our system there are 3 stakeholders: - Faculty, User, Admin (Researcher who has knowledge about metacognition). We have provided various features for each stakeholder as shown in the figure 1.

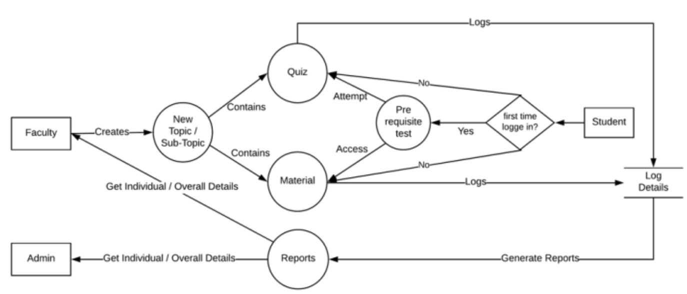

Fig. 2. DFD LEVEL 1

As shown in figure 2, the faculties can create topics and study material, quiz related to the topic. The students can access quiz and material as per their convenience. An Analytical report for each student will be generated by the system based on activity performed by the user while interacting with the system.

Implementation

Implementation Plan

As discussed earlier we have developed the base of our website. Also, our site is hosted on a digital ocean server so anybody can assess our site from a remote location.

Now we are working on the quiz part of the website. Parallelly we are developing algorithms to log the records of quizzes, reference materials, etc. We will then create one more algorithm with some benchmarks in it to generate the analytical report. This report can then be used to assess the metacognition level of students. And based on this report on time scaffolding from the faculties can be provided to students. Coding Standard. We are following all the coding standards for each of our technology stack. The various coding standards such as variable and function naming, code maintenance, and code cleanliness. We are also collaborating with each other using GitHub.

- Use cases

We have created our own test cases, which are based on multiple factors. Based on the meta-cognition assessment inventory, this test cases have been categories into various sub-components. Some of the test cases we have explained here: -

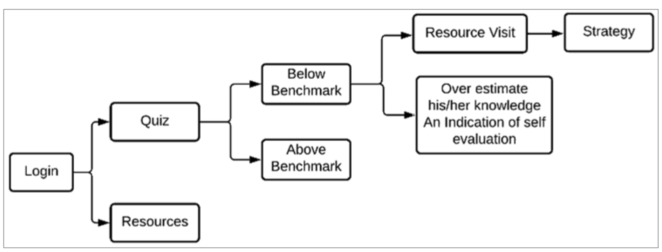

Fig. 3. Use Case Diagram 1

After login, if the user directly jumps to the quiz without reading any resources related to it and scores below the benchmark then two cases are possible.1] The user could visit the resources and again attempt the quiz which shows that it was the strategy of the user to check what kind of questions are asked in that topic and accordingly prepare for that topic. 2] Even though the user is getting a low score and not preparing for that shows the user is overestimating his/her knowledge.

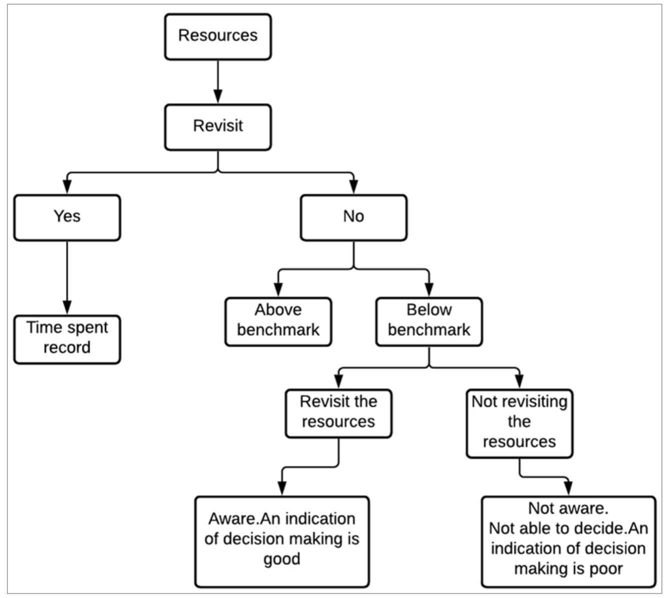

Fig. 4. Use Case Diagram 2

Some do not need to read multiple times to understand and to remember something properly but some need to read multiple times. If the user revisits the resources then we will record the time spent by the user and if the user does not revisit the resource and get below the benchmark at least then he/she should revisit the resource. Still the user not revisiting the resource then we can say he/she is not aware of his/her metacognition and not able to decide and it shows an indication of decision making is poor.

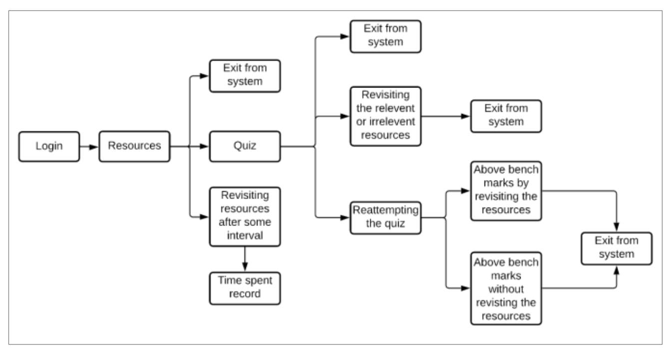

Fig. 5. Use Case Diagram 3

The user visits the resources then he/she can give the quiz or revisit the resource after some interval then we will record the time spent. After giving the quiz, the user can revisit the relevant or irrelevant resources or reattempt the quiz. If he/she gets above benchmarks by revisiting the resource shows awareness of his/her metacognition.

- Testing

We divided our entire project into small modules and implemented them successfully. Then we perform unit testing of individual module at developer side. Further we integrated all modules together. Again, we perform testing on the entire project at the developer end.

We have also asked small group of students to interact with our site. Based on their interaction with our system, we can get to know about the bugs (if any).

- Data analysis

We have collected the data from 15 students in 2 weeks, with 1 week as one interval. As we know that metacognition is a vast area in itself, developing generalized system to assess metacognition through a digital system is complex for that one should have knowledge of each domain. Thus, we reduced our scope of the project to only one domain (object-oriented programming). Based on the data we have collected till date, we observed that very few students were metacognitively aware however many students were lagging behind in one or more sub components of metacognition.
Our site provides this data analysis for each individual in form of various graphs as shown below: -

Fig. 6. Bar graph of subcomponents 1

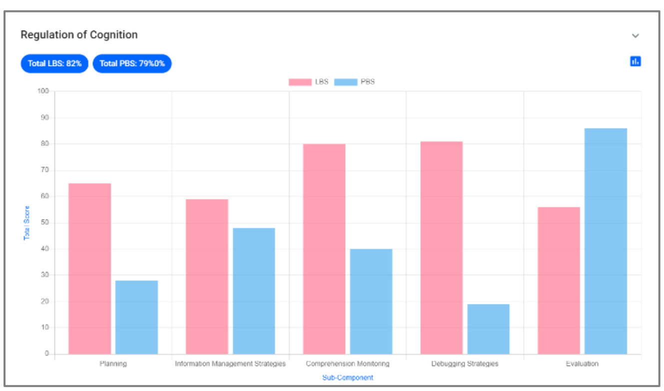

Fig. 7. Bar graph of subcomponents 2

Fig. 6 and Fig. 7 are part of our analytical report which compares the log-based vs perception-based score achieved by the particular student. Based on this analysis, the metacognition level of the individual can be assessed by comparing what they know vs what they think.

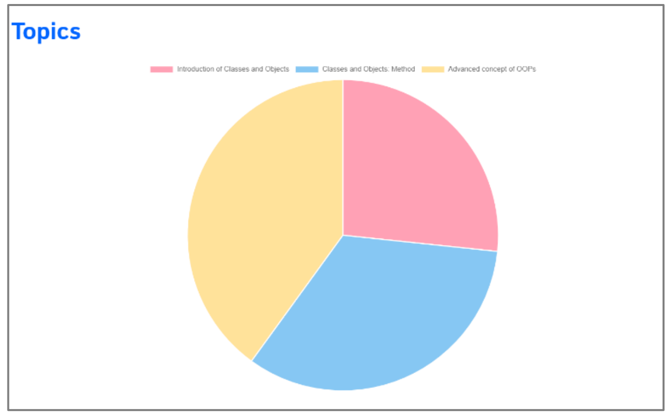

Fig. 8. Pie chart of time spent 1

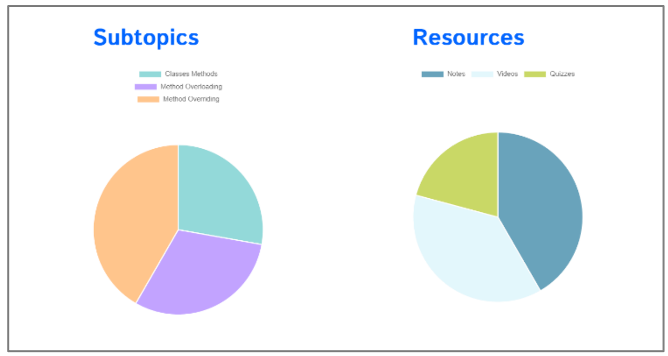

Fig. 9. Pie chart of time spent 2

Fig. 8 and Fig. 9 shows the time spent from various aspects. Fig. 8 indicates the time spent by the students on each topic, the Fig. 9 indicates the time spent on each subtopic and the time spent on various materials such as PDF, video and quizzes. This data analysis can help us to check whether the student was evaluating themselves or not.

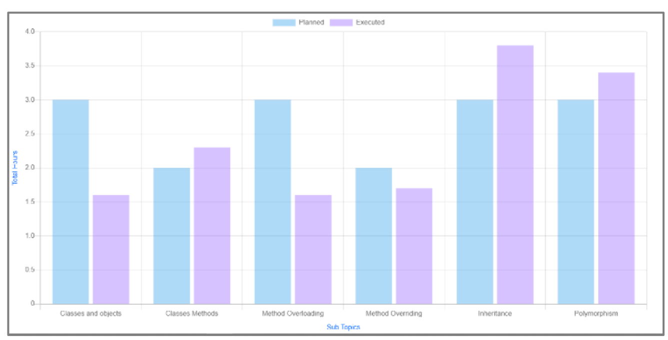

Fig. 10. Bar graph of Planning

Fig. 10 indicates the comparison about what the students had planned at the start of each interval vs what students have actually executed while interacting with the system. This will help us to identify how student is good at planning aspect.
Currently we are also working to generate ‘Qualitative Report ‘of each individual which will help instructor to interpret the findings easily.

Results

We observed that it may take time for individual to develop their metacognitive ability i.e., one might develop it in very short interval of time (2-4 weeks), and one might take long interval of time to develop the same (2-3 months or more). Thus, faculties can provide on time scaffolding based on individual performance.

In the future, more features as well as use cases can be added into our system which will lead to better accuracy towards assessment of metacognition.

IV. Conclusion

We are developing a web-based system which will help academician to access the metacognition level of students, and they can also provide on-time scaffolding for the same. We have focused on only oops concepts to keep area specialization. As we don't have knowledge of each and every domain so it would be very difficult for us to make a generalized system.

So, on the prototype basis, we focused on oops concepts and we will assess the metacognition level of students while they are learning from the materials, quizzes provided by us. Based on students' activity an analytical report will be generated for each student.

In the future, on the successful implementation of this project. A similar process can be used to develop other domain-specific systems or maybe a generalized system can be produced to assess the metacognition level of the student.

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