# Intelligent Tutoring Systems and Metacognitive Learning Strategies: a Survey

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## Introduction

Learning is the ultimate goal and outcome of any education activity. Students need different learning techniques for achieve better learning. Students need different strategies and teaching methods for effective learning in different domains such as mathematics, science, English, physics and not limited to these subjects. Intelligent tutoring systems are educational softaware which are used for learning purpose without inverventaiton of human tutor. Intelligent tutoring system is an extension of Computer Aided Instruction(CAI) which consists of intelligence, feedback, adaptive behavior(Reva Freedman, 2000).

Students find tutoring systems effective and helpful for leraning(Beal and et.al, 2007). A comparative analysis study of effectivnessof intelligent tutoring systems with traditional classroom hasbeen studied(Steenbergen-Hu, 2014). These systems have been developed for different domains such as Metacognitive Mathematics Tutor(Raza,2016), PHP(Weragama, 2013) Animal Watch(Carole R. Beal, 2010), Computer programming (Butz,2006),Physics(VanLehn,2005). WayangOutpost(Arroyo,2004),ActiveMath(Melis and Siekmann, 2001), SQL tutor(Mitrovic,2003), and Andes for physics(Vanlehn,2005). Hints are mostly given in intelligent in tutoring system (Raza,2016; VanLehn, 2005; Carole R. Beal, 2010; Melis, 2001; Arroyo, 2004)

Metacognition is cognition about cognition and regulation of cognition or thinking about thinking (Flavell, 1979). Metacogniton is higher level order thinking component. It is widely studied and researched that metacongionstrenghten the learning of students((Joe Garofalo, 1985). Metacognition is used to reduce cognitive load. When a teacher is asking student to remember English paragraph so he will be use its cognition but how to remember very effectively these strategies are called metacognitive learning straegires, Self explanation, Self explanation, Self Monitoirng, Self assessment, Think aloud are few examples of metacognitive learning strategies.

Students face difficulties in learning different subjects such as mathematics; so for effective learning and lifelong learning. Learning strategies has helped students in improvement of their learning(D'Ambrosio, 1995). Students which are less learner have low metacognition. Students with higher metacognitive skills are successful learners and they are aware of their cognition. Let a student say that he can remember more

than 100 words so he know about his memory how his memory can retain words but when students gives a assignment to remembering English vocabulary of 100 words he could not remember 100 english vocabulary words, so we can say that that studnet metacognition is weak. Metacogniton role in learning is very important so students need to learn about metacognitve strategies.

Students will be aware about their congitoin through metacognition. Students faces any diffilcty in English or mathematics, he can use metacognition learning strategies to scaffold his learning and become better learner. These strategies are now part of teachers instuctions and students actively do practices with mecogntive strategies in classrooms(Hapsari,2020).

Learning performance of students and their metacognition have been widely researched and it has been revealed that metacognition improves the learning performance (Joe Garofalo,1985; Van derstel, 2010; Şahin, 2013). An Intelligent tutoring system with metacognitive support can en-hance the effectiveness of the tutoring system and improvesstudent learning. Metacognition role in students learning has been studied for various subjects such as like chemistry(Rowan W. Hol-lingworth,2001),HTML(kyungbi nKwon,2011),SQLtutor(Najar,2013),Science(Leelawong, 2008) and Mathematics(Raza and et,al,2016).

Different metacognitive learing strategies has been used for learing. In this survey, three metacognitvelearing strategies self explanation, self questioning and self monitoring have been discussed.

Self explanation is metacognive strategy in which students explain learning material to themselves. It has been found that students learn more when explain instructional material to themselves (Chi, 1994). Students which are are better learners also cangenerate more self explanation while poor students can not generate enough self explanations (Chi, 1989).Self explanation is metacognitive strategy used in many intelligent tutoring systems and learning enviroments.Interactive learning enviroment for HTML (kyungbinKwon,2011) used self explanation to self explainduring error anddebugging phase in HTML learning, SQL tutor(Najar,2013)used self explanation to explain understanding of SQL workout examples and after solving problems. Fraction problems with self explanation(Rau, 2009),English Grammartutor with self explanations support (Wylie, 2009).Geometry explanation tutor(Aleven,2004) used two modes of self explanation one is dialoged based and other is menu based self explanation to investigate effects of learning in geometry.

Self monitoring is metacognitive learning strategy process of observing, recording and measuring performance and behaviors (Anastasia Kitsantas, 2009).Self monitoring is a step of self regulation so students can regulate their learning through self monitoring.

It has been found that students involvement in self monitoringis very effective and results in increase ofstudents achievement, probem solving skills and academic success (Schunk,1998). Self monitoring can be used to create students be self direct learners (Steven V. Shannon,2008).Self monitoring also used for English as foreign language in web based learning enviroment which results in improved academic performance(Mei-Mei Chang, 2010). TrAviswhich is Distance education learning environment with self monitoring tools also results positive from students and teachers (Madeth May, 2011).

Self questioning is self regulation strategy which is used to ask questions yourself. It is activity of internally asking questions. It focus on knowledge acquisition and comprehension monitoring by the learner generating questions and this question generation and answering will result in improving comprehension(Wong, 1985). Self questioning strategy used as effective and helpful in learning (King, 1992). Questionbank(Draaijer,2005) developed web based application for supporting self questioning, reading comprehension (Mostow,2009) and Circuit theory(Pate, 2011). Self explanation and self questiong can reduce gaming hint and student can self regulate their learning through self monitoring their performance after viewing their activities during problem solving(Raza, 2016).

Metacognition assessment is very critical task. Metacognition is internal component of students so tools and techniques have been used for metacognition assessment. In this suvery we included different questionares which are used for assessing metacogniton. Self report questionare can be easily used to assess metacognition of students. Jr MAI (Sperling, 2002) is self reportquestionnaire which target younger population. Jr MAI is used by many researchers in which their research objective is to assess metacognition.Jr MAI used as offline method to find which is more efficient for assessing metacognition skills (Seda, 2012).studentsexplored with a science website with two structures linear and non linear and investigated learning in hypermedia environment and its relation with metacognition, Jr.MAI was used to assess students metacognition (Schwartz, 2004).Effects of tutoring on students self regulated learning was investigated and Jr. MAI measure was selected for assessing student self regulated skills(Vandevelde, 2011).

## Intelligent Tutoring System

Intelligent tutoring system is computer software which provide instructions to students similar to human tutor and provide feedback to students. Intelligent tutoring system term in research community first introduced by Brown (Brown, 1982) as an more innovative term for intelligent Computer Aided instruction (ICAI). Intelligent tutoring systemis an *interdisciplinary* field which includes investigations and research studies to devise strategies and learning systems through which students can get more effective and better learning as a good teachers do(Conati, 2009).

Difference between traditional computer based learning system or computer Aided instruction(CAI) and intelligent tutoring systems is that ITS provides feedback and guidance to students about their learning performance without involving of any humantutor.Intelligent tutoring system has lot of advantages, their flexibility of time and place. Student can learn at any time and location through intelligent tutoring so there is no any area limitation (VanLEHN,2011) . Intelligent tutoring systems mainly consists of four modules. These four modules are Interface module, Domain module, Student module and Tutor module.Students interaction with intelligent tutoring system is done in interface module. Graphical user interfaces are used to make more interactive and enjoyable interface for students.

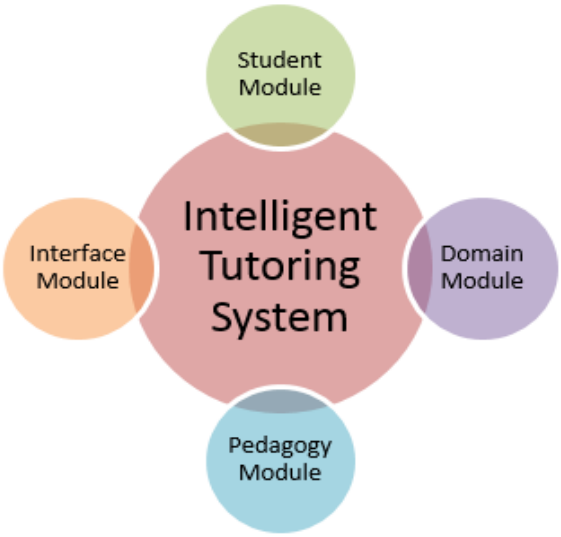


Figure 1. Intelligent Tutoring System

The Domain module is concerned with domain for which intelligent tutoring systemhasbeen designed. It includes how subject knowledge will be represented in the tutoring system.It stores and represents problems, exercises and learning content of the domain.The Student module is concerned with student progress and achievement while using tutoring system. It provides guidance and feedback to students and measure the student learning performance.The tutor moduleconcerned with pedagogy strategies for effective teaching. It is mostly concerned with student module in a way that which pedagogy or instructions system targets towhich students. Intelligent tutoring system take appropriate strategiesusing system feedback of students progress status. ActiveMath(Melis, 2001) is web based adaptive intelligent tutoring system for mathematics. Adaptive activemath provides learning material to students according to their performace, learning goals and achievement. It also produces feedback through evaluation of result progress, navigation which activemath stored in student model. Activemath provides the environment to students according to their learning condition and students are responsible for their own learning. Activemath can be used in teacher assisted learning, computer instructed insutions, home work activity and long distance

learning. Wayang Outpost(Arroyo, 2004) is an intelligent tutoring system developed for Scholastic Aptitude Test(SAT) Mathematics section. Math problems are presented in flash movie and system also helps students with hint. System provides two hints one is numeric and other is multimedia such as animation with audio like drawing or highlighting a task. System results in significant improvement in mathematics learning. Mathesis(Sklavakis, 2013) is web based intelligent tutoring system for school level algebra. Mathesis consist of important component algebra tutor which provides intelligent task recognition and deep model tracing. Mathesis provides all functionalities of traditional classroom such as assignments, assessment and enrollment. Intelligent tutoring system designed for information security subject. Al Azhar university in Ghaza enrolled in information security course participated in study and evaluation of tutoring results are good(Mahdi, 2016). Oracle intelligent tutoring system(OITS) designed and developed for teaching of oracle. Researchers studied effects of intelligent tuoring system on students performance(Elnajjar,2017). Intelligent tutoring system for Introduction to computer science which is compulsory subject in Al-Azhar university have been system integrated in system, which record students program. Effects of systems on students performance was investigated and results showed positive results after students evaluation(Marouf,2018). Intelligent tutoring system for java developed and imporoved students performance after evaluation(Al-Shawwa,2019). Intelligent tutoring system for programming with 3D graphics in Augmented Reality (AR) enviroemnt has been designed(Schez-Sobrino, 2020).

## Metacognition

Cognition are processes which occurs in our mind such as decision making, problem solving, remembering or comprehension. Cognition about cognition and regulation of cognition or " thinking about thinking" is called Metacognition(Flavell, 1979).

Let understand metacognition by an example. A student said that he has good understanking and knowledge of fraction, ratios and proportions of six grade but when teacher gave him problems he did not solved and failed to solve problem or his answer was not right. Other student of English said that he could remember 50 words of English but when he do exercise of rembering English vocabulary it could not remembered 50 words. So which students that he could do that task this is students metacognition. Students did not complete their task claim herself because they did not have knowledge about their cognition or they have poor metacognition. Intelligent Students have strong metacogntion while weak students have poor metacognition. Metacognition in learning is important, so to be effective learner students should have strong metacognitoin. Students can take their own learning resposnibilty by using metacognitive strategies to know about their thinking process and regulate their own thinking. Students could self aware about themselves through metacognitive learning strategies, knows about themselves

such as how well they are doing and they can improve their learning without involving of teacher. So teaching students about metacognition is very critical to students learning.

Metacognition is divided into different types according to theoretical models. Metacognition is divided into two components, Knowledge of cognition and regulation of cognition.Knowledge of cognition is self aware about their

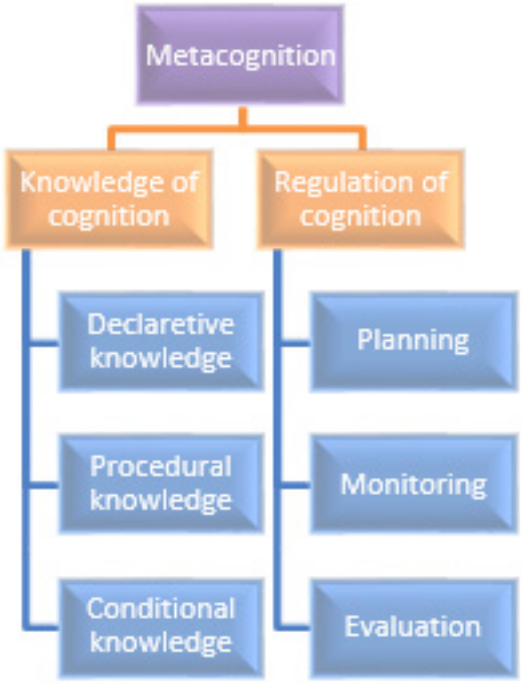


Figure 2. Metacognition

own cognition and thinking process. It includes self awareness, knowing their own thinking process. Knowledge of cognition is further divided into Declarative knowledge, Procedural knowledge and Conditional knowledge. Regulation of cognition is consists of steps to control own cognitive processes. Planning, Monitoring and Evaluating are steps involved in regulation of cognition (Metacognition, Wikipedia) .

In this survey three metacognitive learning strategies self explanation, self questioning and self monitoring have been discussed in below sections.

## Self Explanation

Self explanation is metacognitive learning strategy to explain onself learning material to understand it very effectively each and every line of content(Chi, 1994). Students during reading text, workout example in mathematics explain themselves what they understood. Self explanation is activity of thinking aloud to yourself. Self explanation can be practiced on papers in class rooms and in intelligent tutoring systems in hints (Raza, 2016).

Self explanation can be defined with two processes inference generation and conceptual

revision. Inference generation is used to find students learning about content and it involve struggling for new knowledge through explaining themselves content. Conceptual revision which is reflective in natures used to indentify flaws in students primary mental model with current understating to repair the students mental model of understanding which consequently transfer new knowledge (Chi, 2000).

According to cognitive load theory working memory is limited; self explanation strategy involves explanation content and this explanation generation, inference generation requires high cognitive load. Self explanation with Scaffold learning can used to reduce cognitive load and give confidence to students to generate self explanations for effective learning(Sweller,1988;Sweller, 1998). Students during problem solving activity were asked to generate self explanation and were also judged their self explanation such as high quality self explanations or low quality self explanations, students with feedback performed better in problems as compared to those students who only asked to self explanation without feedback(Cheshire, 2005). Self explanation have been integrated by different researchers for different domains such HTML(Kyungbin, 2011) and SQL(Amir, 2013). Researchers developed interactive learning environment for HTML learning. Open and scafolded self explanations promots used in HTML problem scenarios. Results shows self explanations find effective in learning, increased learning and motivations of students. Interactive Self explanation prompts has been designed for HTML learning. Open and scafolded self explanations were embedded in learning environment for HTML learning(Kyungbin,2011). Self explanations also used to write what is understood after reading examples and problem solving. SQL tutor designed for SQL domain, which consists of SQL examples with self explanations to scaffold learning(Najar, 2013). Geometry explanation tutor was designed with two types of self explanation promots, one is Dialogue based and other is menu based self explanation. Researchers found that Dialogue based self explanion were more effective than menu based self explanation (Aleven, 2004). Single graphical and multiple graphics represention were used for fraction learning. Students were prompted to self explain graphical representations. Self explaination with multiple graphical represention improved fraction learing than self explanation with single graphical representation(Rau, 2009). English Grammer Tutor with self explanations was developed for learning of English as second language(ESL). Two groups one is with self explanation and other with no self explanations were designed(Wylie,2009). Cognitive tutorwas used to investigate self explanation. Two versions of cognitive tutor was used one with scafold explanation and other without self explanation. Results showed significant improvement from pretest to posttest (Aleven,2002). Two studies was conducted first self explanation use in text reading and second is effectiveness o different self explanation promopts (Chou, 2009). Instructinal explanations of expers, teachers and tutors stand alone are not effective, so instructional explanations were combined with self explanations

to scaffold students learning. SEASITE(Self explanation activity supplmeneted by instructional explanations) principle implemented to investigate mixture instructional explanations and self explanations. Prob ability problem scenarios were used to conduct study and their mixture improves students learning(Renkl,2002). Self explanation used to investiage impact on learning, cognitive load and intrinsic motivation and other factors in an interactive multimedia environment(Lin ,2016). Impact of Self-Explanation and Reading Training (SERT) for Introduction to biology course of college students studied and results showed that students with self explanation and combination of instruction improved their science learning(McNamara,2017). Open ended Self explanation strategy used in virtual laboratory learning system used and used Natural language processing(NLP) technology to classify and provide feedback of students self explanations(Huang, 2018). Self explanation used and peer instruction to imporove students physiological concepts(Versteeg, 2019).

## Self Monitoring

Self monitoring is activity of recording, measuring and observing learning progress by itself. It promotes independent learning and student centered metacognitive learning strategy. Students improve their cognition through self monitoring to know *how well you am doing*; it used to control and aware of their own learning process. Self monitoring used to evaluate itself without intervention. Students can increase self efficacy beliefs by control their own learning (Zimmerman, 1995). Students can regulate their cognition through observation and measuring progress. Students can achieve their goals by changing behaviors and discovers their weakness (Anastasia Kitsantas, 2009). Warm up strategy based on self explanation and monitoring integrated with blog based learning system used to help students for better learning(Yih-rueyjuang, 2012). Metacognitive learning strategies can be used to help students self directed learners trhough integration of self management and self monitoring. Anecdotal notes, teacher student reflection and observations used to collect data. Association between learning styles and metacognitive strategies was explored(Steven v. Shannon, 2008) . Self monitoring effect on EFL studens learning performance and motivational beliefs was conducted. Self recording form was used to experiment effectiveness of self monitoring. Results showed improvement in academic performance and positive motivational beliefs (Mei, 2010). TraVis developed for students and teachers to supports students in visualization of communication actions and teachers to do adapt effective pedagogies. TraVis facilitates students for self monitoring to view all activities performance indicator or participation rate(Madeth may, 2011). Metacognitive strategies for self management such as self monitoring and self graphing used to improve math of students. Self management encourage students to take responsibilities of their own learning and monitor academic performance and other activities rather depending on teachers(Anthony Farrell, 2008). Web based learning

environment used for exploring self monitoring, reflection and problem solving prompts on students performance. Study was conducted in two stages; in first students received problems solving and other group did not recieved and in second stage reflective prompts to one group and other without reflective prompts.Metacognitive Awareness Inventory (MAI) was used to assess Metacognition. Results showed that students with prompts improved their performance than without prompts. Learning achievement, self-monitoring, cognitive style, and learning style relationship is studied for medical students. 130 students participated in the study, findings explored positive relationship between achievement and cognitive style and use of metacognitive strategies(Martínez-Bernal,2016). Self monitoring effects on elementary school students with dyslexia have been studied. Results showed that students achievement increased after self monitoring training(Kanani, 2017). Self monitoring used to support instruction in classroom and results showed that self monitoring increased students academic engagement(Ennis , 2018). Effects of self monitoring on elementary students academic engagment studied. Technology based self monitoring intervention called CellF-Monitor used by students. Visual analysized explored positive effects of CellF-Monitor on academic engagement(Schardt, 2019). The relationship between motivation, self monitoring and self management have been investigated and findings explored that motivation affected self monitoring and self monitoring influenced self management so promoting self monitoring and self management skills is very criticial for learners(Zhu, M , 2020).

## Self Questioning

Self questioning is metacognitive strategy is used for teaching and learning. It is used in reading, comprehension and problem solving. Self questioning is used by asking questions onself to monitor congnition which will result in regulation of congnition. This strategy involves learners to ask questiongs during problem solving or any learning activity learners. These questions and question generation technique can be used as tool to think and focus on specific topic. Self questioning effects on secondary levels students with circuit theory course problems were researched; students who practiced with self questioning strategy performed better than other group (Pate,2011). Reading tutor which generate sefl questioning instruction automatically for students to help in reading comprehension and retention. Expert pedagogy is divided into four phases describing, modeling, scaffolding and prompting the strategy. A working example was given to students to practice these phases for given text during reading comprehension (Mostow, 2009). Effectiveness of Self questioning strategy have been researched in web application Questionbook. Frst year 135 marketing students selected for research study and results explored that questionbook is supporting tool for learning (Draaijer,2005). Reading comprehesntion of science text has been studied with three strategies one of them is self questioning. 120 students participtated in study, participants divided into

two groups High proficiency and low proficiency. Results shows that self questioning has positive effects on both groups (Haidee, 2014). Prose comprehension of ESL reading studied, 47 students randomay assigned control group which read text and control group read text with support of self questioning strategy. Results showed that no significant changes developed in prose comprehension and also explored that question generation require verbal ability (Miciano, 2002). Self questioning used in online medical health learning management system(Samadi, 2017). Self questioning used to improve reading comprehension of second semester students of English department(Telaumbanua, 2019). Self metacognitive questioning used to learn quantum physics problems(Dökme,2019). Experimental research have been conducted for Self questioning effects on reading comprehenstion of narrative text of Grade VIII. Results showed that strategy increased students reading comprehension(Marzuki,2020).

## Metacognition Assessment

Metacognition can be assed with two measures online and offline measures. self report questionare such Junior Metacognitive awareness inventory(Jr. MAI) and teaching rating are examples of offline measure while think aloud protocol is an examples of online metacogntion assessment (Seda, 2012). Students explored Sciene website used as learning resource for two and five hours independently without intervention and their Metacognition has been assessment with Junior Metacognitive awareness inventory(Jr. MAI) and How I study Questionare(HISP) used for Metacognition assessment(Schwartz, 2004). Two studies one is Relationship between Science achievement, metacogntion and Epistemological beliefs, second is gender, socioeconomic status, Metacognition and epistemological beliefs have been studied. Junior Metacognitive awareness inventory(Jr. MAI) and Schommer epistemological belief questionare(SEQ) was used to collect data from students(Topçu,2009). Students tutoring effects on self regulated learning studied. Self regulated learning interview schedule(SRLIS) used to assed twelve self regulated learning and subscale learning motivation from Learning Motivation Test(LMT) and Jr. MAI Form B also finished by students (Vandevelde, 2011). Researchers used Motivated Strategies for Learning Questionnaire (MSLQ) to measure self monitoring and Embedded Figures Test (EFT) to measure cognitive styles (Martínez-Bernal,2016).

## Conclusion

This paper presents the survey of intelligent tutoring systems, metacogntion learning strategies and metacogntion assessment. Inteliigent tutoring systems are learning software which used for learning without intervention of human tutor. Metacognitoin learning strategies used in intelligent tutoring systems, classrooms to support students learning. Self explanation, self monitoring and self questioning are metacognitive stragies which used by students and teachers to scaffold their learning. Metacogntion is inner element

of mind so self report questionares used to assess metacogntion of students.

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