Metacognitive components in smart learning environment

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Abstract. Metacognitive ability in digital-based learning process helps students in achieving learning goals. So that digital-based learning environment should make the metacognitive component as a facility that must be equipped. Smart Learning Environment is the concept of a learning environment that certainly has more advanced components than just a digital learning environment. This study examines the metacognitive component of the smart learning environment to support the learning process. A review of the metacognitive literature was conducted to examine the components involved in metacognitive learning strategies. Review is also conducted on the results of study smart learning environment, ranging from design to context in building smart learning. Metacognitive learning strategies certainly require the support of adaptable, responsive and personalize learning environments in accordance with the principles of smart learning. The current study proposed the role of metacognitive component in smart learning environment, which is useful as the basis of research in building environment in smart learning.

1. Introduction

The new paradigm of today's intelligent education focuses on contextual, personal and unlimited learning issues to improve student intelligence and facilitate problem-solving skills in intelligent environments [1]. Seamless learning can be done collectively and individually, not limited by space and time. Individual learning takes into account the personal characteristics of students, learning styles and students' cognitive abilities. Contextual learning takes into account the background, condition and location of learning. So intelligent learning is a convergence of development in epistemology, psychology, and technology. Implementation of the convergence is a smart learning environment [2].

The international association for the Smart Learning Environment argues that the learning environment is considered smart if it utilizes adaptive technology or is designed to include innovative features and capabilities that enhance understanding and performance [3]. The innovative and adaptive capabilities of a technology in learning are technological skills that involve new needs in learning. To meet those needs intelligent learning has two types of technology that must exist, namely smart devices and intelligent technologies [4].

The intelligence of technology to respond to students 'personal abilities is the intelligence to understand learning styles and assess students' cognitive skills. In addition there are aspects involved are the metacognitive ability of students [5]. In the field of educational technology and information science it is stated that metacognitive strategies are important in overcoming problem-solving barriers [6]. Even in modeling of students in digital environments requires the expansion of discrete knowledge statistics of students' holistic assessment of student profiles in the cognitive, metacognitive and affective domains [5]. With metacognitive ability, students are not only aware of strategies but also knowing when and how to use problem-solving strategies. Without using metacognitive
strategies, one does not know how to analyze the answer, fails to allocate enough time to study, or does not want to know how much he has learned about a subject, then, every learning task seems as though it was encountered for the first time [7]. Various metacognitive components will be studied in depth along with its function. This component can be part of the development of the next smart learning environment design.

Section 2 in this paper is a review of the relationship between the smart learning environment and the students' metacognitive abilities. Section 3 contains metacognitive roles and functions in the smart learning environment to enhance learning service, Section 4 highlights several technologies to facilitate the service, and Section 5 illustrates the conclusions and work to be done next.

2. Related Work
This section is a review of metacognitive research in e-learning and the smart learning environment and the linkage between the two from a general perspective.

2.1. An Introduction to Metacognitive
Brown (1977) in [8] revealed that metacognitive skills are skills in solving problems of self-awareness in efficient problem solving which includes planning and scheduling problem-solving strategies, monitoring and evaluation of problem solving. Even disclosed earlier by Flavel (1976) in [8] that the inability of students to solve problems is more due to metacognitive deficiency than cognitive.

Metacognitive has two groups of components namely metacognitive knowledge and metacognitive regulation. Metacognitive knowledge refers to one's own cognitive processes consisting of knowledge of personal variables, knowledge of task variables and knowledge of strategy variables, while metacognitive regulation refers to one's procedural knowledge to organize cognitive processes with four components of planning, monitoring, evaluating and revise [9]. Metacognitive ability means the awareness of one's self towards his knowledge so as to understand the tasks to be performed and the strategies to be taken.

A person who has metacognitive skills means having the ability to know how to learn. Skills include the ability to question his/herself against self-study resources, the ability to look back at self-checking resources [10], the ability to monitor self-learning progress (self-monitoring), the ability to explain self-learning materials in the domain of self-explanation and the ability to learn from analogical reasoning [11]. The ability to know how students learn independently, procedurally can be done with components in the metacognitive regulatory group.

2.2. Improved Metacognitive Ability
There are several techniques that can help students in improving metacognitive skills. Scaffolding technique is a technique for the learning process with the gradual aid to students who then gradually reduce the aid to increase the knowledge and competence of students. Scaffolding theory has become a major topic since it was discovered in Vygotsky's research, which became a key topic in modern learning research [12]. This technique is directives, questions and commands that involve students to improve their cognitive abilities. Because each student has different metacognitive abilities the facilitator will provide assistance according to his/her abilities.

In addition to scaffolding techniques, there is a help-seeking technique, with this technique, the facilitator will monitor the help options that will indicate students' cognitive abilities so as to stimulate their metacognitive ability to plan for problem solving. The research on help-seeking was developed by Roll in [13] as part of the tutor system to assess the students' quiet moment-learning behavior. Assessment of feedback outcomes consisting of general instruction and self-assessment combined into help-seeking error, i.e. assessing the student's mistake in choosing each help-seeking step. The help-seeking behavior measurement technique is performed by Vaessen in [14], i.e. calculating frequency and orderliness in selecting clues to solve the problem.

Some examples of such techniques are directed to capture the stages of students' metacognitive abilities composed on certain smart devices and of course with improved accuracy later. Data from
smart devices are processed by intelligent technology to provide valid conclusions about the stages of metacognitive ability and then respond according to metacognitive strategies developed.

2.3. Smart Learning
Electronic-based learning technology or e-learning at first just an information technology-based learning, radio and broadcasting but continues to be integrated with the development of technology until the emergence of intelligent technology [15]. At the time of the development of mobile technology, learning can be done with notebooks or mobile devices, but using wireless internet, making the form of learning becomes unlimited by place and time, which then becomes m-learning [16]. There are four components to be studied in the development of mobile-based learning communities, namely human factors, learning subjects, mobile technology support systems, and human support systems [17].

The next emerging technology is ubiquitous computing, this technology integrates learning into ubiquitous learning or u-learning. Learning can be done anywhere anytime with any device without having to use personal computer, just use internet connection [1], [18]. The latest developments are learning with intelligent technology, the technology emphasizes student-centered learning, which tends to be informal [15]. Learning that facilitates sensitivity, responsiveness and adaptive to student conditions. Smart learning is not just serving the interaction of students but also captures all interactions to be managed in the analysis tool then gives conclusions about the condition of student development to provide appropriate response to the condition of students.

2.4. Smart Learning Environment (SLE)
Hwang defines SLE as a learning environment technology that makes adaptation and other provision support at the right place and time according to student needs. The framework has been compiled by him illustrating that the learning environment contains five module components, such as, student state detection module, student performance evaluation module, adaptive learning task module, adaptive learning content module and personal learning support module as well as an inference engine. The personal learning support module is supported by data on learning ppifolio, student duty sheet and student profile [16].

Like Hwang, Gros also agrees that SLE is not just a learning system that can be used in any place and at all times, but also actively provides learning guides, guides and adaptive support tools according to the right place, time and form [4].

SLE not only contains the components of intelligence tools, learning resources, the student community, and the teaching community, but also the way of learning and teaching. These two components make the learning environment "intelligent" according to the different needs of learning. [19]. Huang and colleagues have proposed further research to improve the quality of SLE with a more comprehensive coverage area covering education, computer science, psychology and engineering. Of course with the support of the latest technologies such as intelligent systems, internet of things and cloud computing. SLE focuses on user experience as a developmental principle that prioritizes personalized learning and a shift in the role of teacher from instructor to facilitator.

From the two points above, the problem raised in this paper is that metacognitive is an important factor in the learning process that emphasizes the focus on the personalization of learning, [9], [11], [12], and if the smart learning environment is Adaptive technology serves students' personalization needs [16], [4], then how SLE becomes adaptive to the improvement of students' metacognitive abilities, what components support them.

3. A Proposed Smart Learning Environment Components
Metacognitive is a learning factor that emphasizes the personalization of learning. As mentioned above, students' ability to solve problems is strongly influenced by metacognitive ability. Techniques used in the process of developing metacognitive abilities, such as scaffolding and help seeking require students' responses to assess their development. Another section of the above review revealed that
smart learning not only serves interaction, but also has to capture student interaction. The problem of the development of metacognitive ability and the need of smart learning is the component of learning environment which always catch the interactive and adaptive response to the development of students' metacognitive ability.

The SLE component proposed in this paper is an environment that focuses on adaptive services on improving students' metacognitive abilities. Any student who has the same cognitive ability may have far different metacognitive abilities that lead to different cognitive development. Awareness activities of self-knowledge and ability for self-learning can be done with metacognitive skills improvement techniques. Components in SLE-metacognitive are arranged in the form of modules connecting students, inference engines, environments and supporting databases.

The first SLE component is the student's cognitive ability detection module is a component to capture prior knowledge possessed by students. The result of this component becomes a learning portfolio and a benchmark of student development. The form can be done with pre-test or feedback to the questions posed.

The second component is the metacognitive technique module, this module contains steps that provide direction for improvement of metacognitive ability. If the technique used is scaffolding, this module contains gradual help with feedback to evaluate its metacognitive enhancement. If the technique used is help-seeking, this module contains sequences and hint branches that can be tracked for their accuracy so that they can be evaluated for their metacognitive capabilities.

The third component is the learning content management module. This module provides instructional materials that are sequential and staged according to the level of content understanding. Each content has relevance to the stages in the metacognitive technique module.

The fourth component is the adaptive assignment module. This module receives prior knowledge information, and metacognitive level information. Then with the help of the inference engine analyzing the prior knowledge level of the students, and making the decision to provide appropriate metacognitive technique steps then re-evaluating the feedback, the feedback evaluation results are re-used for subsequent assignment according to the student's ability. This is done in an iterative way until the students are able to solve the problem.

The fifth component is the inference engine as part of intelligent technology is an intelligent device that contains various algorithms to define the student's cognitive level status, determines the metacognitive status of the students so that students can be helped to decide the choice in planning their knowledge enhancement.

![Figure 1: Relationships between components](image)

### 4. Technologies for Smart Learning Environment

Smart Learning Environment for supporting students’ metacognitive skill is greatly helped by the rapid development of technology. Completeness of features of mobile devices such as tablets, smartphones and various wearable computers supported by wireless communication networks and sensing technologies such as Computer Vision, Voice Capturing, RFID, and GPS [18], [20], can meet SLE-metacognitive needs.

For example, a group of students from different places and at the same time, can study the same subjects even with different devices. Suppose they will study math subjects on integrals, the cognitive
ability detection module will detect their prior knowledge of integrals. A variety of user interfaces can help capture the cognitive abilities of every student. Through the monitor screen on a tablet or smartphone can provide questions and receive student answers. Sound counseling technology can conduct interviews. Computer vision technology can capture the faces of students when given a particular problem. The GPS device can record the student's environmental conditions. All data about students along with initial cognitive abilities become student profile notes.

The metacognitive technique module, referring to the inference given by the inference engine will provide knowledge assistance. The extent to which assistance will be provided, the inference engine provides a decision based on the results of the cognitive ability detection analysis. Certain student groups may be helped with understanding the basic formula to help resolve integrals. Other groups of students may receive the help of differential understanding or even start from basic numerology. All the subject matter along with the level of help is managed by the learning content management module. To capture the development of capabilities after the provision of assistance, the adaptive assignment module will provide tasks according to the level of assistance provided.

The SLE-metacognitive component will be greatly helped by Augmented Reality (AR) technology. AR integrates problems into the digital world just like the real world [21]. When students face their own problems, students will encourage themselves to learn independently, the above four modules will help to self-questioning and self-checking and monitor his ability with cell-monitoring. The integration of real-world and virtual presence in AR will deepen the metacognitive role in the learning environment.

5. Implications
As mentioned above, metacognitive is an important part of the learning process, individually or in groups from various places and times. Crucial elements needed to support metacognitive modules are smart devices such as Internet of Things and other wearable technologies that support and intelligent technology such as learning analytics or big data that focuses on learning data [4].

Therefore, the procurement of metacognitive components in learning becomes a logical implication in the development of the smart learning environment, it is an investment in social capital and communication infrastructure that plays a major role in improving the quality of human resources [22]. Smart infrastructure with intelligent components built by the government into the building base in building smart city [3].

Thus the smart learning environment with metacognitive components can be implemented in the context of smart city governance. Governance that provides a holistic focus for decision making that defines and delivers all educational components and even all other components of the smart city including mobility, environment, economy and society [22].

6. Conclusion
Information and communication technology is growing rapidly accompanying the development of the concept of intelligent learning. The presence of smart devices and intelligent technology add to the discourse of the development of smart learning environment, forming new ideas for improving the quality of learning.

The role of the field of study of educational psychology and computer science is very strong to form smart learning environment, but still have to involve again other fields such as education technology, this field will play a lot on instructional instructional, curriculum and some other learning technology.

According to bloom, learning is not just for cognitive development, but also student behavior, social ethics and psychomotor ability. This will be the field of future work in the smart learning environment involving computer science experts, educational psychology and teaching technology.
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