Cognition and Instruction/Metacognition and Self-Regulated Learning

This chapter introduces the basic concepts of metacognition and self-regulated learning, explores how learners take an active role in their own learning through self-regulation. We examine the different models of self-regulated learning (SRL). We discuss the theory of metacognition and SRL and show how these fundamental cognitive processes drive learning in academic settings, as well as how to facilitate SRL in the classroom.

After reading this chapter, you will learn:

- The concept and major models of SRL.
- The concept of metacognition and its importance for students to reconstruct knowledge and manage their learning strategies.
- The major factors that affect SRL and metacognition.
- How learning analytics promote research in SRL.
- How technology can facilitate SRL.
- The four stages in the development of self-regulation, and the four types of SRL strategies.
- How to Facilitate and encourage SRL in the classroom.

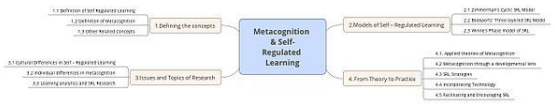

Figure 1. Metacognition and Self-Regulated Learning

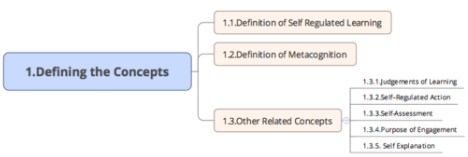

Figure 2. Defining the Concepts

1 Definition of Self-Regulated Learning

Self-Regulated Learning (SRL) is that learners have ability to monitor and control their own learning processes [1]; it is concerned with the learners' use of different cognitive and metacognitive strategies to control, monitor, and regulate their cognition, behaviour, and motivation in their learning.[2] Learning in a self-regulated way, learners can set their own learning goals, control their learning processes, and motivate themselves when they participating, in order to achieve their goals [3]. In a SRL environment, learners can be more active and efficient for their learning performance and behavior to improve their final learning outcomes. Self - regulated learners have abilities to change and develop their own learning strategies based on self-understanding [4]and examine their learning through constructive activities, collaborative work, and free exploration. SRL is a cognitively and motivationally active approach to student-centred learning.

As "a behavioural expression of metacognitively guided motivation" (Winne & Baker,2013, p.3)[5], the process of SRL assists learners in managing their thoughts, behaviors, and emotions in order to successfully navigate their learning experiences. This process requires learners to independently plan, monitor, and assess their learning.[6]

According to Zimmerman (2002), SRL can be broken down into three phases during learners' cognitive and behavioral activities: the forethought phase, the performance phase, and the self-reflection phase. The forethought phase (self-assessment, goal setting, and strategic planning) involves analyzing the learning task and setting specific goals toward completing that task. [2] The performance phase (strategy implementation and strategy monitoring) takes place during learning, and self-reflection phase can be the evaluation of learning outcome.[7]. By adopting this method, learners can be better understood through viewing specific strategies which they use to engage in their own learning. The large scale structure of self-regulated learning is as follows and the detailed explanation will be provided in later section of this chapter.

2 Definition of Metacognition

Metacognition is one of the key components in self-regulated learning, which involves cognitive thinking and regulation of thinking. Learners who have metacognitive ability, can be able to monitor, control, regulate their own learning. [1] In this section, we will look at how the definition of metacognition has evolved.

In 1979, Flavell first introduced the concept of metacognition in his research.[8] The concept of metacognition can be related to various aspects in learning process, which includes reading, writing, planning, and evaluation. Both monitoring and controlling of cognition are two basic functions served by metacognition.[9] In 1980, Ann Brown provided a definition of metacognition, which not only majorly address on the relationship between knowledge and regulation of cognition, but it also the first time brings up the word "regulation". [1] Recently, the concept of metacognition has been mentioned in so many research and usually divided into three components: [9]

Metacognitive knowledge also called metacognitive awareness. As cognitive processors, each individual learners should know about themselves, tasks, strategies, goals, and other relevant information.[9] There are three different types of metacognitive awareness, i.e. declarative knowledge, procedural knowledge, and conditional knowledge. [10]

Metacognitive experiences are "what the person is aware of and what she or he feels when coming across a task and processing information related to it". [9] It is very important in self-regulated learning because it allows learners to make attributions about their feelings and adjust their own goals.

Metacognitive skills/strategies are the "deliberate use of strategies (i.e. procedural knowledge) in order to control cognition, which include orientation strategies, planning strategies, strategies for regulation of cognitive processing, strategies for monitoring the execution of planned action, and strategies for the evaluation of the outcome of task processing".[9] Similar to metacognitive knowledge, metacognitive regulation or "regulation of cognition" contains three skills that are essential: planning, monitoring, and evaluating. [11]

In these three components, metacognitive experiences and metacognitive knowledge are related to the monitoring of cognition, and metacognitive skills/strategies focused more on controlling of metacognition. The definitions of metacognition have conceptualized metacognition as "multifaceted", "conscious process", and "individual phenomenon". In order to study metacognition in the self-regulation processes, we need to combine "different experimental methodologies that implicate the self (e.g., feedback, social comparison) along with measures of metacognitive experiences and affect". [9]

A number of interventions have been developed in education that involve three components of metacognition. For example, interventions provide metacognitive experiences to control learners' cognitive learning. The interventions usually emphasize on the metacognitive knowledge of strategies and the procedures that involved in metacognitive experience over time. Specifically, metacognitive interventions can also assess self-regulated learning and identify reasons why metacognitive regulation is failing, "that is, if it is metacognitive knowledge, metacognitive skills or metacognitive".[9]

3 Other Related Concepts

3.1 Judgements of Learning

A topic related to metacognition is Judgements of learning. Judgments of learning (JOLs) are "assessments that learners make about how well they have learned particular information".[12] Nelson and Dunlosky (1991) define that judgements of learning "help to guide self-paced study during acquisition". It's more accurate when it's happening shortly than immediately after study. This implies learners should evaluate their learning process after waiting for a short time. In addition, they call the way of learners self-evaluation "Delayed-JOL Effect" and they believe that judgements of learning can be self-monitoring during learning.[13]

Feeling-of-knowing judgment refers to the "degree of accuracy for recognizing or knowing a task or answer and predicting one's knowledge",[14] which is similar to the concept of judgments of learning. Both "Feeling-of-knowing" and SRL concept are connected because of metacognitive accuracy. The concept of Metacognitive Accuracy will be discussed later in this chapter.

3.2 Self-Regulated Action

Self-regulated action shows the way of how regulation is conducted. Both object and action are the major components of Self-regulated action. To better explain this, the object is the learning goal that learners set up at early stage of their learning and the action is how the particular learning goal have achieved by learners. Actions can include changes in cognition, emotion, motivation, behaviour, personality attributes and physical environment.[15] For instance, the action of motivation can be directly affected by how and when learners have the ability to complete their learning tasks. The action of behaviour from individual learner will also impact on each individual learning ability and goal achievement.

3.3 Self-Assessment

Self-assessment makes people reflect on their abilities and their strategies. It requires choosing techniques that

are most appropriate for the information needed to learn. It occurs in the first stage of self-regulated learning. Making self-assessment requires the learners to be motivated, and have the will and effort to adopt new learning techniques. Self-assessment requires a positive attitude towards learning.[16] A positive attitude and an open mind about learning techniques can enhance the process of self-assessment. Questions you can ask yourself may be: What are my skills? What are my Interests? Do I learn by watching videos or taking notes? Do I learn better by writing or typing out notes? Do I learn best by memorizing and explaining? [4]

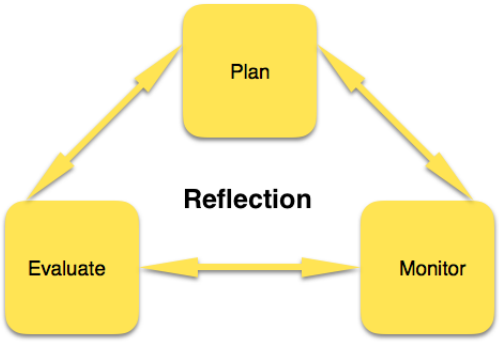

Figure 3. Self-Regulated Learning Process

3.4 Purpose of Engagement

Purpose of engagement is a combination of self-process, purpose, and possible actions that are relevant in a specific learning situation[15]. Each individual learner has different reasons for engagement of their own learning. For example, some learners want to learn because they are interesting about particular knowledge, and some of them learn because of their workplace needs. In this way, they will have different motivating factors, which will lead their learning process. During learners' self-regulated learning process, their engagement mainly display in their plan, monitor and evaluate their learning. A more detailed table of the self regulated process and how students regulate their personal functioning, academic performance and learning environments is as follows:

3.5 Self Explanation

4 Zimmerman's Cyclic SRL Model

Zimmerman's Cyclic SRL Model divides self-regulated learning process into three distinguished phases: forethought phase, performance phase, and self-reflection phase. The forethought phase refers to processes and beliefs that occur before efforts to learn; the performance phase refers to processes that occur during behavioral implementation, and self-reflection refers to processes that occur after each learning effort.[2]

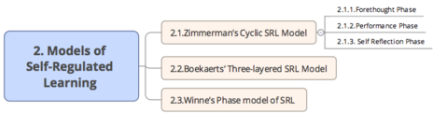

Figure 4. Models of Self-Regulated Learning

4.1 Forethought Phase

There are two major classes of forethought phase processes: task analysis and self-motivation. Task analysis involves goal setting and strategic planning. Self-motivation stems from students' beliefs about learning, such as self-efficacy beliefs about having the personal capability to learn and outcome expectations about personal consequences of learning.[2]

Goal Setting is looking at what you need to achieve and how to get there in a specific time frame[4]. Goal setting requires a basic understanding of the information need to be learned, because in order to set a goal learners must have some knowledge in what the outcome should look like. Goal setting is important because it helps create motivation and can motivate learners to accomplish a specific learning goal. It is essential to create attainable goals which you are capable of reaching. Therefore the goals set should neither be too high nor too low; it should be in your realm of attaining and succeeding. Attainable goals promote desire and motivation because they are more likely to be accomplished. There is considerable evidence of increased academic success by learners who set specific proximal goals for themselves, such as memorizing a word list for a spelling test, and by learners who plan to use spelling strategies, such as segmenting words into syllables.[2] Some questions that one could ask themselves to goal setting are as follows: What do I want to achieve? What steps will take me to my goals?

Strategic Planning is similar to goal setting in that learners need to have a basic understanding of the learning content. After goal setting, learners should plan specific strategies to achieve those learning goals.[4] Strategic Planning is a more detailed way to reach learning goals. A strategic plan consists of a number of small goals within a bigger goal. To make a good plan, learners need to understand the learning tasks, learning objectives, and the direction they want to pursue. [4]

For example, if one had seven days to study for an exam covering fourteen chapters, he can separate the learning into studying two chapters per day. By strategically planning how much he need to study everyday, the final

goal of learning fourteen chapters in seven days will be achieved. Strategic plans can also be used to reach athletic goals. E. g., in order to accomplish a marathon training in one month, one can create a timeline of how much he should improve each week, and how long he should run each day and each week, so he can add the workouts of each day and each week to reach the final goal.

In order to help developing strategic plans, learners could ask themselves some kinds of questions, such as: What is my purpose of the learning? How will I reach my learning goals? How can I implement my learning strategies to reach my goals? Do I have enough time to accomplish each goal? Are my goals realistic in this specific time frame? How should I study for this specific goal? How does my personality affect me reaching those goals? What might distract me when I am learning?

Self Motivation Beliefs include self-efficacy, outcome expectations, intrinsic interest, and learning goal orientation. [2] Self-efficacy in this case is students' belief about their ability to learn a task. For example, when a student is learning a difficult concept in the class, he may feel he is going to understand it easily or he might fear that he is going to get lost. "Self-efficacy is extremely important for self-regulated learning because it affects the extent to which learners engage and persist at challenging tasks. "Higher levels of self-efficacy are related positively to school achievement and self-esteem. [17]Teachers can enhance self-efficacy by providing learning tasks with appropriate levels of difficulty and with an appropriate amount of scaffolding. Schraw, Crippen and Hartley suggest that there are two ways to enhance students' self-efficacy. "One is to use both expert (e.g., teacher) and non-expert (e.g., student peers) models", "The second is to provide as much informational feedback to students as possible". [17] Outcome expectations are personal expectations about the consequences of learning, such as students believe that they can learn a difficult concept in economics class and are going to use this knowledge in the future. Teachers can promote outcome expectation by reminding students that the information is going to be useful in the future. Intrinsic interest refers to the students' valuing of the task skill for its own merits, and learning goal orientation refers to valuing the process of learning for its own merits. Students with high intrinsic interest are more motivated to learn in a self-regulated fashion because they want to acquire the task skills. A student who wants to become a teacher, for example, might study the educational knowledge really hard.[2] Teachers can enhance the intrinsic interest by introducing the application of knowledge. Teachers can enhance learning goal orientation by making the class entertaining or intrigue students' attention using different modality (video clips, graphs).

Schraw et al elaborated the motivation component, in science self-regulated learning, as a composition of self-efficacy and epistemological beliefs. Epistemological beliefs are "those beliefs about the origin and nature of knowledge". These beliefs affect problem solving and critical thinking, which are important component of self-regulated learning.[17]

4.2 Performance Phase

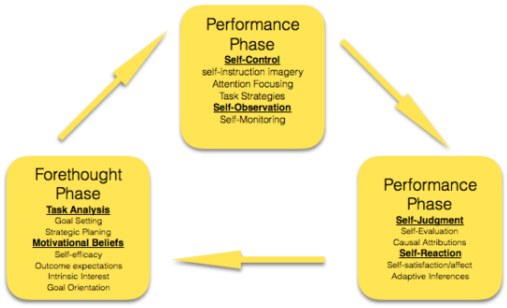

Figure 5. Zimmerman's Cyclic SRL Model

Performance phase processes fall into two major classes: self-control and self-observation. Self-control refers to the deployment of specific methods or strategies that were selected during the forethought phase. Self-observation refers to self-recording personal events or self-experimentation to find out the cause of these events. For example, students are often asked to self-record their time use to make them aware of how much time they spend on studying. Self-monitoring, a covert form of self-observation, refers to one's cognitive tracking of personal functioning, such as the frequency of failing to capitalize words when writing an essay.[18]

Self Control processes, such as self-instruction, imagery, attention focusing, and task strategies, help learners and performers to focus on the physical task and optimize their solution effort. For example, self-instruction involves overtly or covertly describing how to proceed as one executes a task, such as "thinking aloud" when solving a mathematics problem. Imagery, or the forming of vivid mental pictures, is another widely used self-control technique to assist encoding and performance. A third form of self-control, attention focusing, is designed to improve one's concentration and screen out other covert processes or external events during problem solving.[18] Volitional methods of control, such as ignoring distractions and avoiding ruminating about past mistakes, are effective in enhancing problem solving.[19] Task strategies can assist problem solving by reducing a task to its essential parts and reorganizing them meaningfully.[20]

The second major class of performance phase process is **self-observation**. This refers to a person's tracking of specific aspects of his or her own performance, the conditions that surround it, and the effects that it produces.[21] Learners who set hierarchical process goals during forethought can self-observe more effectively during performance, because these structurally limited goals provide

greater focusing and reduce the amount of information that must be recalled. Regarding the accuracy of self-observations, individuals who fail to encode and recall their prior solution efforts can not adjust their strategies optimally.[18]Self-recording can provide the learner with more accurate information regarding prior solution attempts, structure that information to be most meaningful, and give a longer database for discerning evidence of progress of problem solution efforts.[22] Self-observation of one's performance, especially in informal contexts, can lead to systematic self-discovery or self-experimentation.[23]

Strategy implementation is the process of which learners deploy strategic learning plans and actually applying these plans into learning practice.[4] Strategy implementation requires motivation and self-determination. Learners must have a solid strategic plan to prevent environmental distractions and understand what will motivate and demotivate the learning in achieving the goals. Strategy implementation is important in the success of learning experience, because it affects the efficiency and effectiveness of learning. It addresses how and where the learning will occur and is one of the most important factors for learners to reach their learning goals.

Strategy Monitoring is the process of monitoring how effective the strategic plans are for facilitating learning. By monitoring the implementation of learning strategies, the progress of learning tasks and how the environments affect the learning processes, learners can assess how effective their learning is, and adjust the strategies as needed so that the best learning experience could take place.

4.3 Self Reflection Phase

There are two major classes of self-reflection phase processes: self-judgment and self-reaction. One form of self-judgment, self-evaluation, refers to comparisons of self-observed performances against some standard, such as one's prior performance, another person's performance, or an absolute standard of performance. Another form of self-judgment involves causal attribution, which refers to beliefs about the cause of one's errors or successes, such as a score on a mathematics test.

Self Judgement: There are four main types of criteria that people use to evaluate their problem solving: mastery, previous performance, normative, and collaborative. Mastery criteria are absolute indices of a solution, such as comparing a crossword puzzle solution with the author's solution. When solving problems in unstructured informal contexts, learners must often rely on non-mastery standards, such as comparisons of their current performance with previous levels of performance. Self-comparisons involve within-subject changes in functioning, and as a result, they can highlight learning progress, which typically improves with repeated practice. Normative criteria for self-evaluating one's learning involve social comparisons with the performance of others, such as classmates or during a national competition. A collaborative criterion is used primarily in team endeavors towards accomplishing learning tasks.[18]

Self-evaluative judgments are linked to causal attributions about the learning outcomes, such as whether a failure is due to one's limited ability or to insufficient effort. Attributing a poor score to limitations in fixed ability can be very damaging motivationally because it implies that efforts to improve on a future test will not be effective. In contrast, attributing a poor math score to controllable processes, such as the use of the wrong solution strategy, will sustain motivation because it implies that a different strategy may lead to success.[2]

Self Reaction: One form of self-reaction involves feelings of self-satisfaction and positive affect regarding one's performance. Increases in self-satisfaction enhance motivation, whereas decreases in self-satisfaction undermine further efforts to learn. [24] When learners condition their self-satisfaction on reaching their problem-solving goals, they can direct their actions and persist in their efforts much better. [25] Self-reactions also take the form of adaptive/defensive responses. Defensive reactions refer to efforts to protect one's self-image by withdrawing or avoiding opportunities to learn and perform, such as dropping a course or being absent for a test. In contrast, adaptive reactions refer to adjustments designed to increase the effectiveness of one's method of learning, such as discarding or modifying an ineffective learning strategy.[2]

Outcome Evaluation : Outcome evaluation takes place after learning has occurred. It reviews the learning goals, the strategic plans, and evaluate how effective they were.[4] Outcome evaluation is very important because it helps learners to improve the efficiency and effectiveness of their learning practices and create a better plan for the future learning processes. Questions that learners may ask themselves could be: How practical were my goals? Were they attainable? How accurate was my strategy plan? Should I have included any other strategies which I did not? What should I change about my learning in the future? Was my environment distracting?

5 Boekaerts' Three-layered SRL Model

6 Winne's Phase model of SRL

Figure 6. Issues and Topics of Research

7 Cultural Differences in Self – Regulated Learning

The concept of learning, and self-regulated learning in particular, relates to cultural differences. Most information on 'self-regulation' and the 'concept of learning' are Western views. This is a one-sided approach to understanding self-regulation. Being exposed to different cultures, people are also exposed to different ways of thinking.

When Japanese students studied in Australia,[26] they learnt different learning strategies and found new ways to understand knowledge than what they were used to. This process may have been unconscious but because they were put into a new system with a different language and a different structure, they were forced to change some of their learning strategies. Viewing learning from different perspectives makes people realize that knowledge is not necessarily dualistic. This means that knowledge is not right and wrong, or good and bad. Knowledge is something flexible and dynamic and, therefore, it can be questioned. The stereotypical view of Asian culture on learning is that knowledge is something learnt by an authority figure who knows right and wrong and that it is something that need to be memorized. This results in the assumption that students from Asia are passive learners who are compliant, obedient, and absorb knowledge rather than understand it. The stereotypical view of Australian students is that they are more active learners, as they are characterized "by assertiveness, independence, self-confidence, acceptance of diversity, and a willingness to question and explore alternative ways of thinking and acting".[26]

8 Individual differences in metacognition

Another popular topic in the studies of metacognition is the issue of individual differences. Research of individual differences in metacognitive ability shows that this issue makes metacognition very difficult to measure. Winne (1996) proposed that there are five sources of individual differences affecting metacognitive monitoring and control in self-regulated learning. These are: "domain knowledge, knowledge of tactics and strategies, performance of tactics and strategies, regulation of tactics and strategies, and global dispositions". (Winne 1996, p. 327)[27] Global dispositions refer to dispositions about learning. Winne emphasized that his proposals are tentative and require further investigation. However, his research encouraged other researchers to dive into this topic.

Figure 7. Different Mind

A number of researchers suggest that individual differences in metacognitive accuracy reflect differences in metacognitive ability, however Kelemen, Frost, & Weaver (2000) suggested that this is not the case. Metacognitive accuracy refers to "the relationship between metacognition and future memory performance"(Kelemen et al., 2000, p. 92).[28] The study measured four common metacognitive tasks: judgements on "ease of learning", judgements on "feeling of knowing", judgements of learning, and text comprehension monitoring. In the study, including pretest and posttest, memory and confidence levels were stable. However, individual differences in metacognitive accuracy were not stable. This suggests that metacognitive accuracy is not reliable when it comes to measuring individual differences in metacognitive ability. It should be noted that the validity of research is questionable, as a lot of researchers acknowledge the difficulty of measuring metacognition. Further research is required in the field.

The notion of individual differences in metacognitive ability also suggests that there is no one-size-fits-all solution for metacognitive instruction. Lin, Schwartz and Hatano (2005) suggest that application of metacognition need to be proceeded with careful attention to differences in individual learning and classroom environment.[29] They also suggest teachers to use adaptive metacognition which involves "both the adaptation of oneself and one's environment in response to a wide range of classroom variability" (Lin et al., 2005, p. 245). [29]Classroom variability includes social and instructional variability. In order to implement adaptive metacognition, Lin et al suggest an approach called Critical Event Instruction which "help teachers appreciate the need for metacogni-

tive adaptation, particularly in situations that appear routine on the surface level" (Lin et al., 2005, p. 246).[29] This approach helps prepare preservice teachers deal with commonly occurred problems in the classroom. It provides information on how to deal with different values, goals and experiences.

9 Learning analytics and SRL Research

9.1 Defining Learning Analytics

In fields ranging from business to epidemiology, propagation of computer use and the increase of computational power has created opportunities for extracting, analyzing and reporting useful information from large datasets. In education, similar methods for dealing with 'big data' are referred to as learning analytics. Although often presented as a new discipline, learning analytics has been formed by ideas, principles and methodologies that have been around for some time. Its roots are multi-disciplinary, combining elements from artificial intelligence, statistical analysis, machine learning, business intelligence, human-computer interaction and education.[30]

What is Learning Analytics?

The Society for Learning Analytics Research (SoLAR) provides the following definition for the field of Learning Analytics: "Learning Analytics is the measurement, collection, analysis, and reporting of data about learners and their contexts, for the purposes of understanding and optimizing learning and the environment in which it occurs."[31] Synthesizing the different definitions suggested by various experts in the field,[32][33] the following points can be inferred about the nature of learning analytics:

- The discipline involves techniques, methodologies, frameworks and tools that are implemented to deal with data.
- It focuses on data deriving from learner behavior and activity in various educational settings. Actually, as Siemens (2013) suggests, the origins of the data can be traced to various levels of education, from individual classrooms to international curricula.[30]
- Its scope extends in every phase of data manipulation: data capture, with tools that are actually used to collect the necessary data, data analysis, with tools that aim at finding structures and patterns in the data, and data representation, with tools creating visualizations of data to be used further.
- It has a theoretical aspect, as the analysis of the educational data may lead us to a better understanding of the learning process, providing the necessary empirical evidence to support relevant theories.
- It has a practical aspect, as the results of these data analyses and interpretations may provide new ways to manipulate and thus optimize learning environments and the learning process in general.

Factors that facilitated the increased use of Learning Analytics Even though the narrative of learning analytics, in terms of its focus, is not new, there were certain developments and factors that reinvigorated the interest in the field, resulting in its establishment as a distinct discipline. The most prominent of these factors are the following:

- **Quantity of data**

The quantity of educational data available to be further analyzed has been greatly increased, especially after introducing digital devices in various learning contexts, like blended modes of instruction, learning management systems etc.[30] When learners use digital media, they leave a "digital trace" of their interactions in the form of data that are easily captured and stored for further analysis. That kind of data may include logging times, posts, number of clicks, sections of the material visited by the student, components that have been used and for how long etc. Subsequent analysis of the data could lead to interesting insights on the learning activities and the deeper cognitive processes related to them.

- **Increased processing / computation power and more efficient algorithms**

Certain advances in computation facilitate the analysis of the large quantities of educational data available. Computational power has greatly increased, making possible data analysis in shorter periods of time, while new algorithms on machine learning and artificial intelligence allow the discovery of patterns and constructs in the data without immediate human supervision of the procedure.

- **Data formats**

Capturing the necessary data for analysis is not enough. The data have to be in a usable form, in order to be processed efficiently. That is the role of standardized formats for logging specific types of educational data. [34]Having those formats beforehand saves us a great amount of time that was needed to prepare the data for analysis and interpretation.

9.2 Key methods and tools of Learning Analytics

Siemens (2013) distinguishes two major components of learning analytics, techniques and applications. Techniques include computational elements (algorithms and

models) that are used for analyzing the educational data. Applications are the actual implementations of these techniques in educational settings, in order to achieve specific goals like adapting the learning environment to the user or creating learner profiles.[30]

In this section, the major techniques and methodologies used in Learning Analytics are presented, along with some examples of possible applications, which outline the ways that these techniques can be applied to learning environments and other educational settings.

Prediction methods

A simplified description of the function of these methods is to identify the value of a specific variable (which is called the predicted variable) by analyzing a set of other aspects of data that relate to other variables (which are called **predictor variables**).[35] For example, there are prediction methods that collect data from various activities of students in an online course (log in times, blog activity, performance in assessment tests – **predictor variables**) to determine the probability of failing the course (predicted variable). These prediction models can be used in two types of applications: to predict future events, like student dropout [36] or student outcomes in courses [37]. There are also cases of data that cannot be collected directly, as this will intervene with the students' activity. In these cases, prediction models allow the researchers to infer the necessary data by measuring other sets of variables.[38]

Structure discovery

This Learning Analytics technique appears quite different from the previous one, as it includes algorithms that have the goal to discover structures in educational data without previous hypotheses on what it is to be found. There are several methods to achieve this goal. In **clustering**, the objective is to organize data in groups, with the result of splitting the data set into a set of clusters. These clusters can be, for example, student groups, categorized on how they use exploratory learning environments.[39] In **social network analysis**, patterns of relationships and / or interactions between learners are identified. This method have been used for many different studies, like determining how students' behavior and status in a social network relate to their perception of being part of a community.[40]

Relationship mining

This technique is used as a method to detect relationships between variables in the case of large data sets with a high number of different variables. The most usual goals of this method is to discover which variables are more strongly associated with a specific variable or to pinpoint the strongest relationships between variables. There are several applications for this Learning Analytics technique. Baker et al. (2009) managed to compute correlations between several features of Intelligent Tutoring Systems and the students' tendency to "game the system" (= intentionally misuse the system in order to proceed with the course without actually learning the material).[41] In another study, Perera et al. (2009) used this method to analyze data, in order to determine what path of student collaboration leads to successful completion of group projects.[42]

Distillation of data for human judgment

This technique involves several methods of refining and presenting educational data, using appropriate visualizations, in order to support basic research as well as the practitioners of education (teachers, school leaders, administrators etc.). For example, Bowers (2010) used visualizations of student trajectories spanning over several years to identify patterns that would predict which students are at risk. The rationale was that there are certain common patterns among successful or unsuccessful students that can be identified and which, when appearing, can be considered an indication for the student's success or failure.[43]

9.3 Learning Analytics and research in SRL

Considering the previous section on Learning Analytics methods and applications, it is obvious that these tools provide the empirical evidence to form and support theories on learning. Research in the domain of self-regulated learning isn't an exception. Several studies have been conducted using learning analytics methods and tools, in order to explore the field and test hypothesis on the nature of self-regulation and the conditions under which it appears.

Issues and challenges in Self regulation research

The continuously expanding use of computer-based learning environments brought a subsequent increase of the interest in research of self-regulation. The reason for this is that these new learning applications present important opportunities for learning, leading researchers to examine how successful students are in taking advantage of this potential and the conditions for this success. [44]These learning environments provide a high degree of learner control and, hence, opportunities for self-regulated learning. Learners are able to approach the content on multiple ways, decide on multiple ways of representations, manipulate several parameters of the environment etc. However, this also means that learners lacking the necessary self-regulation skills may face the possibility of failing the learning objectives of these resources. Therefore, it is crucial to capture and assess self-regulated learning behaviors of students in these environments, in order to further understand the nature of these cognitive processes and to design interventions and scaffolds to support them.

Several issues and challenges in capturing and assessing self-regulated learning behavior have been identified by

researchers and experts in the field, especially due to the internal nature of the processes involved. In examining or measuring self-regulation of learners in computer-based learning environments, it is very important for the researchers to adopt a specific theoretical model for SRL. Siadaty et al. (2016) emphasize the fact that, in order to have valid interpretation of the measurement of self-regulation, "the selection, development and deployment of a measurement method (or a combination of methods) should align with the underpinning SRL model or theory" (Siadaty et al., 2016 p. 190).[45] However, there are cases of studies that do not acknowledge a specific theoretical model or framework, thus resulting in lack of clarity about terminology and definitions.[44] Additionally, in certain research studies specific aspects of self-regulated learning models are addressed, like goal setting, self-monitoring or self-efficacy. These approaches, isolating and treating these aspects as individual elements, do not provide an accurate picture of the role the pieces play in the larger construct of SRL.[44]

Another issue in self-regulated learning research lies in the method of data collection used in the several studies. The majority of relative studies use as the major source of data self-reports of the learners who use the learning resources. The accuracy and overall quality of the data are highly dependent on the students' learning awareness, as well as their skill to describe their actions and strategies when interacting with the learning environment. As Winters et al. (2008) point out, these student self-reports are not always as accurate as observational techniques.[44] Other studies rely on think-aloud protocols as their primary source of data. These methods can capture self-regulated processes as they occur and in a more accurate way. However, the use of these protocols is focused on identifying strategies and processes used, ruling out the examination of their quality, i.e. how successful the students are in using and implementing these during their learning. As an example, summarization is a very effective learning strategy. However, the degree of effectiveness is not determined by merely implementing or not this strategy, but also by the quality and the conditions of summarization, in relation to the learning objectives (the time of summarization, how it is conducted, the choice of topic etc.).

Finally, an important issue to the researchers when deciding on the data collection and measurement tools is how intrusive they are in the learning procedure. The ideal capturing method is the one that functions in parallel with the learner's interaction with the system and collects data without interfering with the learning process in any way. This kind of "unobtrusive" behavior appears in learning analytics data collection tools. These tools are tracing the user's actions, as they interact with the system, log times, features of the environment that are used more frequently, performance in assessment activities etc. to discover patterns of actions that provide evidence of self – regulation. The use of learning analytics in investigating self-regulated learning will be further discussed in the next section.

Capturing Self Regulated Learning behaviors using Learning Analytics

Learning analytics techniques and applications provide accurate and non-intrusive data collection methods, in order to trace and further analyze empirical evidence of self-regulation processes, during the learners' interactions with the learning environment. Additionally, recent developments in computer science provide highly sophisticated methods to collect trace data on these processes, enriching the variety of tools that are in the researchers' disposal.

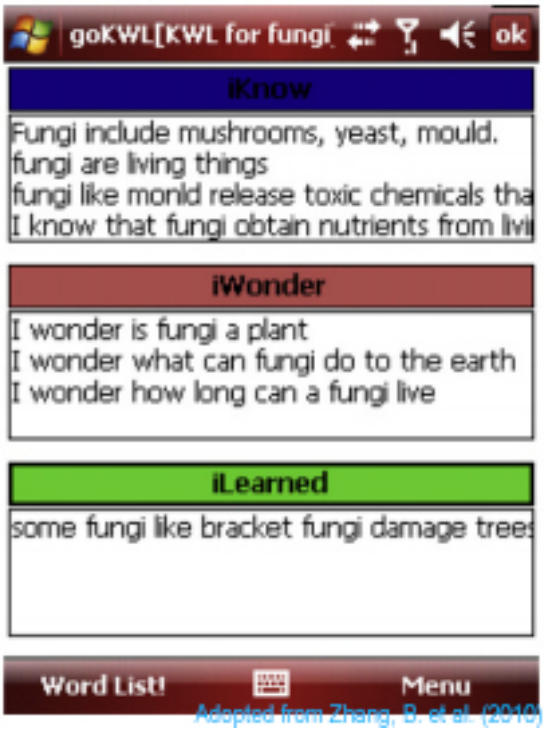

Figure 8. KWL

As we have already seen in the previous section, the majority of relative studies on self-regulation uses as the primary source of data students' self-reports, with all the challenges that this choice entails. However, there have been studies that have used a blend of self-report surveys, online behavioral data and learning outcome measurements. Sha et al. (2012) attempted to explore patterns of self-regulated learning during the use of a mobile learning environment. That specific study involved primary school students (Grades 3 and 4) that used the affordances of a mobile learning platform to learn science. The platform was used in the context of the official curriculum in Singapore. The learning platform included several applications for a variety of purposes, like drawing animations, creating concept maps and creating KWL tables. The students' actions and performance on the latter application (iKWL) was the data source that was used in the study. More specific, this application consists of

three pre-designed questions that students answer before, during and at the end of each lesson (see also Figure 8): What do I know?, where the students bring their prior knowledge to the task, What I wonder?, which functions as a goal setting component and What did I learn?, that refers to the self-reflection phase of self-regulated learning. The researchers' intention was to explore the characteristics of the learners' engagement in answering the KWL questions. In order to measure this, two variables were implemented: one indicating whether or not a student completed the KWL table (0 if none of the fields were completed and 1 if at least one of the fields was completed) and another indicating the degree to which each student completed the table (rubric that measures number of items inserted in each category). This measurement is rather simple, so it can be performed automatically by the system, without examining anything about the quality of content for these insertions. [46]

Figure 9. Posterlet

There are studies that focus on investigating specific aspects of self-regulation strategies implemented by learners in computer-based learning environments. Cutumisu et al. (2015) in their study investigated the effectiveness of the strategies "seeking negative feedback" and "revision" to the learning outcomes, for primary school students using a learning application named Posterlet. This learning environment enables students to design posters for a school's Fun Fair. The learning objectives accommodated with this resource is for the students to learn principles and practices of effective poster design (optimal graphical and textual characteristics). The component for capturing that specific learning behavior is embedded as a feature to the learning environment. In particular, the learners design a poster using the several tools provided by the environment and then receive feedback on their product, in the form of positive (I like…) or negative (I don't like…) comments by animal – agents (see also Figure 9). The system captures two learning choices made by the students, the number of times a student chose the negative feedback option and the number of times a student revised his / her product. The data collected were strictly numerical. No measurement of the quality of revisions (whether the students' revisions were directed by the feedback they received by the system) had been made during the study.[47]

Figure 10. MetaTutor

There are certain learning environments that have a dual role in terms of self-regulated learning: learning tools, which are designed to teach and support self-regulation behaviors, and research tools, used to collect data on students' self-regulation behaviors. Such a case of a learning application is MetaTutor, used in the research studies by Azevedo et al. (2013). MetaTutor is a learning environment with biology science content, using multiple agents to guide and support students in using self-regulated learning strategies when interacting with the platform. Several of its features refer to specific self-regulation stages and processes (goal setting, planning, self-monitoring, self-reflecting) and they are seamlessly embedded in the system's interface (see also Figure 10). Additionally, MetaTutor includes data collection mechanisms which are used to collect information on user interactions, in order to provide researchers with the necessary data to investigate self-regulation processes, but also to provide students with the necessary formative feedback, in order to support and further expand their self-regulation skills. The system uses a range of sophisticated learning analytics techniques, apart from the usual ones (self-report surveys, think aloud protocols), in order to capture and assess self-regulated learning. An eye-tracking component is used to infer valuable information about how learners navigate and explore the content, in which parts they focus, the order they access the information, the parts of the diagrams that they use etc. These data are very important, as they reveal information about processes that may not be mentioned in the students self-reports or think- aloud sessions. The system also traces data from various processes and interactions that relate to self-regulated learning strategies and which are being deployed by students to facilitate the learning procedure. Examples of these data traces include note-taking patterns or drawing behaviors, as well as event-based traces of the students' interactions (key strokes, mouse clicks, accessed chapters or activities, performances in quizes etc.). The data are subsequently analyzed and patterns or sequences of actions are discovered, in relation to specific self-regulation processes and strategies. The synthesis of all these different types of data provides the researchers with an insight of the subordinate cognitive processes.

For example, the longer time a student spends when reading a text indicates increased cognitive processing of textual content, or tracking the user's transitions from text to diagrams and graphs indicate an attempt to integrate multiple representations of informational sources. There is also an elaborate facial expression recognition component. The system collects video data of students' facial expressions, which are subsequently analyzed by specialized software (Noldus FaceReader 3.0) and the students' emotional states are determined. The drawback is that the system recognizes a limited number of basic, universal emotions, that don't represent the whole range of emotions that students experience when interacting with the learning environment.[48]

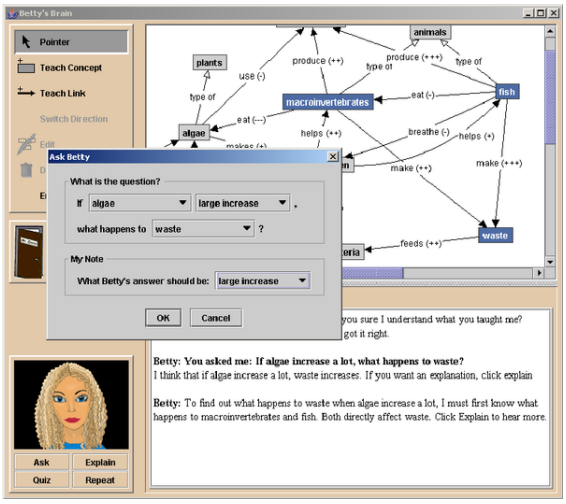

Figure 11. Bretty's Brain

Finally, there are studies that use specific components of learning applications that are related to certain self-regulation stages, implementing the data collected by these components to discover structures in the data (see also clustering in section 2). Segedy et al. (2015) incorporate a similar data collection method in an approach to self-regulation learning research which they call **coherence analysis**. In their study, they are using a learning application called Betty's Brain. In this learning environment, students attempt to teach a virtual agent, Betty, about a science phenomenon, by constructing a causal map. This map (see also Figure 11) consists of entities, which represent key concepts of the phenomenon, connected by directed links, which represent causal relationships between concepts. Betty uses this causal map to reason using chains of links and to provide answers to various quiz questions.[49]

The correctness of the causal map will determine the ability of the agent to answer correctly these questions. The students infer these causal links by acquiring the necessary information from specific texts they are provided, test their causal maps against certain quiz and, depending on the feedback, revise them to achieve higher accuracy. Analyses of the data collected during the students' interactions with the program determined 5 different groups of students, depending on their behavioral patterns. The first group, frequent researchers and careful editors, spent large amounts of time viewing sources of information and not so much on editing their causal maps. Group 2, strategic experimenters, spent enough time viewing information, without actually taking advantage of that. Their edits of the causal map, though, are more frequent than group 1. Group 3 can be characterized as confused guessers and they edit their causal maps frequently but without support from the science resources. Group 4 involves students disengaged from the task. These students have a high proportion of unsupported edits and they spent more than 30% of their time in the system in disengaged mode. Group 5, engaged and efficient, have a high edit frequency on their causal maps and most of these were supported. These students had also high viewing time and potential generation time. That behavior is actually the one that makes students succeed in Betty's Brain.

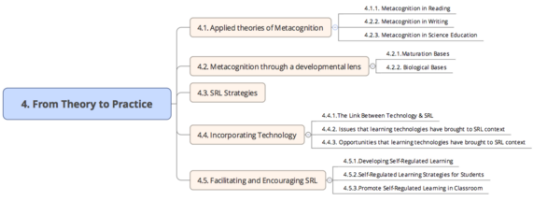

Figure 12. From Theory to Practice

10 Applied theories of Metacognition

10.1 Metacognition in Reading

Recent research on metacognition and its effect on reading comprehension includes studies and individuals with language disorders and adolescents. These studies show relationship of metacognition with reading and writing, as well as the applicability of metacognitive interventions. Furnes and Norman (2015) compared three forms of metacognition (that is metacognitive knowledge, metacognitive skills, and metacognitive experiences) in normally developing readers and readers with dyslexia.[7] Participants read two factual texts, and their learning outcomes were measured by a memory task. Metacognitive knowledge and skills were assessed by self-report and metacognitive experiences were measured by predictions of performance and judgements of learning. The results showed that reading and spelling problems of individuals with dyslexia are not generally associated with lower levels of metacognitive knowledge, metacognitive strategies or sensitivity to metacognitive experiences in reading situations. A longitudinal study on normally developing children indicated that girls have better metacog-

nitive knowledge between age 10 −14.[15] The study also revealed that text comprehension is positively correlated with individual differences in metacognitive knowledge of strategy use. These two studies suggest that text comprehension in dyslexia is not related to the students' metacognitive skills, metacognitive knowledge or metacognitive experiences. However, for normally developing children, their text comprehension is related to their level of metacognition.

Question generation often helps students understand the texts better. "An ideal learner – self-regulated to active – is a person who asks deep questions and searches for answers to thought -provoking questions" (Garcia et al. 2014, p. 385).[4] A number of research has been done to determine the effect of question generation to reading. García et al. (2014) examined 72 ninth-grade students in science class. The results indicated that "question-generation training influenced how students learned and studied, specifically their metacognition" (Garcia et al. 2014, p. 385).[4] Participants in group 1, who received question-training by providing prompts had the highest score on metacognitive knowledge and self-regulation. This suggests that effectiveness of question generation depends on the person's metacognitive knowledge. It is important for teachers to recognize students' metacognitive skills before letting students generate questions.

10.2 Metacognition in Writing

Metacognitive abilities are essential in writing, especially in university level courses. Although instructors often urge students to reflect on their writing and revise it several times, it is rare for students to actually evaluate and re-work their writing in a detailed fashion. Parrott and Cherry (2015) brought up this concern and suggested a new teaching tool to make students think about their writing more actively. The strategy is called **process memos**.[50]

Process memos are guided reflections submitted from students and teachers. Students submit process memos after writing the first drafts and the final versions of their papers. For the first draft, students are asked to reflect on their paper, the helpfulness of the rubrics, questions regarding the assignment, the strengths and weaknesses of their paper, and what they think they need to improve in the final version. After this, teachers mark the paper and provide feedback. In the second process memo, students are asked to reflect on the feedback they received from the teacher. Questions include "which comments were most helpful, and why?" (Parrott et al, 2015, p. 147).[50] Parrot et al. started testing out process memos in 2005 and fully implemented it in a study in 2015. The study included 242 university students in various sociology courses, including introductory courses and more advanced courses. [50]The results suggested that process memos help both students and teachers to actively engage in the process of writing. Teachers get feedback on their instructional qualities so that they can improve their teaching in the future and make sure the rubrics are clear. Although some students did not take process memos seriously and provided insufficient comments, most students found this method useful in improving their writing skills. Most students were honest about their comments. Process memos also promoted communication between students and teachers, as they allowed teachers to directly respond to students' reflections. Another advantage of using process memos, according to Parrot and Cherry is that they engage every student in the class, so students who feel too shy to raise their hands and ask questions in class can benefit. It is an efficient way to enhance students' metacognitive awareness, and guide students' writing step by step.[50]

10.3 Metacognition in Science Education

As mentioned before, metacognition is important in the field of science education because higher levels of science require students to reconstruct perceptual knowledge and procedural strategies on their own. It is also important for students and teachers to be aware of their beliefs about science, as they affect their learning and teaching respectively.[17] However, a number of teachers take these beliefs for granted. A study (Abd-El-Khalick et al., 1998) where researchers interviewed pre-service teachers and students revealed that not many teachers teach beliefs about science or the nature of science. Some teachers in this study believe that teaching the nature of science is not as important as teaching other concepts in science. [51]

This becomes a problem when students proceed to university and learn higher levels of science. It also affects students' motivation to study science because it hinders their understanding of science. Schraw, Crippen & Hartley (2006) agrees to this and state that "effective instruction should help students and teachers aware of the beliefs they hold about science" (Schraw, Crippen & Hartley 2006, p.117).[17] Then, how do we promote metacognition in science learning? Schraw et al suggest that "authentic inquiry promotes metacognition and self-regulated learning because students are better able to monitor their learning and evaluate errors in their thinking or gaps in their conceptual understanding"(Schraw et al, 2006, p.119). [17] This is part of the inquiry based learning that many researchers believe it is effective for science teaching. In inquiry based learning, students pose questions and construct solutions. Another way to enhance metacognition in classroom, as suggested by Schraw, Crippen and Hartley, is by collaboration among students and teachers. This will promote feedback, modeling and social interaction, which will benefit in students' motivation and epistemological beliefs. Similarly, metacognition and self-regulated learning is highly discussed in math learning and instruction research. Please refer to the Learning Mathematics chapter for more information.[17]

11 Metacognition through a developmental lens

Research shows that metacognitive abilities are related to factors such as age and biology (citation 4). It is therefore important to understand the developmental progression in order to apply the theory.

11.1 Maturation Bases

Age as a factor

- Young children
  - Theory of Mind
- Adolescents
- Adults

11.2 Biological Bases

Deficits in learning

12 SRL Strategies

Self-regulated learning is a vastly growing topic of interest, especially within the field of educational psychology (Rosman et al., 2015). [52]The goal lies in seeking to integrate theories into a cohesive framework that can be used to guide educators and learners. In a review of the literature regarding self-regulated learning, Paris & Paris (2001) summarize several principles as being practical applications of SRL in the classroom environment.[53] They categorized them within the confines of four ideas that integrate the research in this field. Firstly, students are capable of better understanding what learning entails when they can make self-appraisals. This means that by analyzing their ways of learning and comparing it to others, evaluating what they have and don't have knowledge about, and assessing their efforts students can enhance their awareness of the process of learning. Secondly, self-management of thought and affect allows for greater flexibility in the ability to problem solve adaptively. By setting realistic goals that focus on improving their competence, effectively managing their time through continual monitoring, and reviewing/revising learning strategies students can commit to higher performance standards for themselves. Thirdly, with respect to instruction self-regulated learning can be taught in a variety of ways that allows for accommodation. SRL may be taught to students explicitly (directed reflection, discussions around metacognition, practice with experts); it can be taught indirectly (modeling, and reflective practices); and it can be prompted with individualized mapping of growth. Lastly, it is believed that self-regulation is intertwined with the narrative experiences related to identity for each student. The way in which students choose to assess and monitor their behavior is consistent with the identity they desire and by being a part of a reflective community of learners/instructors, one can enhance the level of depth by which they look at their self-regulated learning.

While there may be variation in the ways in which students self-regulate, the importance lies in understanding how children come to self-regulate in the first place. According to Paris & Paris (2001), SRL can be enhanced in three ways: (1) Indirectly through experience: repeated exposure to experiences in school can elicit learning of what is expected by the teacher and what is most beneficial to the student.[53] An example of this is the learning that double-checking work, although initially time-consuming, can be beneficial in the long-run and will therefore be advantageous to do the next time around also. (2) SRL can be taught directly: students can learn from the explicit instruction of educators who highlight effective strategy use, and increase awareness of the importance of goal-setting. As an example, an instructor may emphasize the strategic steps of how to analyze a word problem from start to finish. (3) Self-regulation can be elicited when integrated with active practices that embody SRL within them. An effective practice that encompasses SRL into it is collaborative learning projects where each student takes on responsibility for a portion of an overall project. Self-regulated learning appears throughout such projects as students are bound to learn from the feedback of others, and from analysis of what they have done to contribute to the whole. These three outlined ways of enhancing SRL are often found in combination as students get exposed to experiences with their peers and instructors in their educational environment.

Throughout education, students are taught various learning strategies to incorporate into their studies; yet as research shows, it is not always enough to know such learning strategies but to be able to regulate the use of the strategy effectively (Leutner et al., 2007). In a computer-based training experiment by Leutner, Leopold, and Elzen-Rump (2007), the researchers were able to show the benefit of not only teaching students a useful cognitive learning strategy (highlighting) but of additionally providing training on how to monitor and regulate the use of this tool with metacognitive learning strategies. [54]The study involved 45 college students randomly assigned to either a treatment group that received no training at all, one in which they were trained only in the cognitive strategy of highlighting, and the other in which training on highlighting was combined with training on self-regulation in learning about new-born babies. The combined self-regulation training group had a version of the computer-program that included steps on how to obtain metacognitive control with time to practice the control strategy and apply it in the next section of their text learning. The results of the study indicate that students trained

in both strategy-use and metacognitive control of this strategy use were more successful in applying their learning in a goal-oriented way when tested after the training. The cognitive-strategy use only group performed better than the control group, which received no training at all; however the combined training group outperformed both, indicating that, while strategy use can improve outcome performance, learning can be enhanced even further when students are taught to regulate such strategies.

13 Incorporating Technology

13.1 The Link Between Technology & SRL

The undeniable growth in technological use, Prensky (2001) in his article, suggests that teachers must find ways to use technology to enhance students' learning experience. Also, teachers must know the "needs" of students and take advantage of the available information, combined with computing power, to deliver content to digital natives in a convenient and comfortable manner.[55][56][57] Today, technology interventions can consist primarily of learning tools for the digital natives' self-regulatory learning process and goal achievements [57][58]. Students are comfortable trying different kinds of new technologies to plan their own learning activities, monitor themselves, and self-evaluate their own learning outcomes.[59][56] In regards to students, their previous knowledge, interests, and motivation can directly influence their individual learning experiences, performances, and outcomes in technology enhanced SRL environments.[56]

For example, Ma et al. (2015) provide the example of Intelligent Tutoring Systems (ITSs) being implemented in learning environments to investigate the possibilities and approaches of using technologies to support students' learning outcomes. ITSs as computer systems, bring intelligence to computer-based instruction by engaging students in learning activities and interaction according to their behavior.[60] ITSs provide knowledge of the subject domain and "can perform task selection by characterizing each task as a set of production rules required to complete it and each student as a set of production rules that most need to be practiced, and then finding the best match" (Ma et al., 2015, p.4). [60]ITSs provide an opportunity for each individual learner to choose and monitor their own tasks, which can be more effective and useful for students who have different knowledge levels and learning abilities. The individualized learner-control options provided by ITSs can encourage students to assume control over their learning, which will promote their self-motivation and foster their self-regulated learning [61][62]

Kauffman, Zhao, and Yang (2011) have come to similar conclusions as Ma et al.'s regarding the use of technologies to facilitate and support self-regulation and metacognition among learners.[63] More specifically, Kauffman et al. (2011) find that the use of technologies in educational settings can help people to teach and learn through multimedia and in organizing course content. For instructional designers and instructors, they can create and deliver the course content through both web-based pedagogical and multimedia tools to their students. Various media formats can help educators to maintain the attention of learners, increase their learning interests, and better integrate them in the self-regulated learning process (Kauffman et al., 2011).[63] On the other hand, learning through multimedia can help learners obtain relevant information to complete tasks and "provide them multiple options to view the course content in various media formats" (Kauffman et al., 2011, p.43)[63] that will increase their learning interests and help them engage in self-regulated learning. In addition, the content creation tools will employ powerful learning strategies, enabling learners to demonstrate their understanding of course content through media formats to monitor and evaluate their own learning process (Kauffman et al., 2011).[63]

13.2 Issues that learning technologies have brought to SRL context

The increased rate in which students have been using digital technologies has introduced many challenges to SRL.[61][62][56][59]One of the biggest challenges is that technologies cannot fully monitor learners' understanding and are controlled by learner themselves, which can be less effective in developing the students' cognition skills during SRL. In this way, learners lose their freedom to learn in SRL process and they have to receive verbal feedback and explanation from educators during their learning process to better understand the flow of information.[64]For instance, Learning Management Systems (LMS) distribute learning content, organize the learning processes, and build connections between learners and teachers through the interface. However, students do not really get any freedom in their own learning process on the LMS. Instead, teachers monitor their understanding the whole time when they participate in LMS courses.[61] [62] In contrast, Personal Learning Environments (PLE) give each student opportunities to select and control the services they want to use instead of control over content and learning strategies. Lack of guidance in course content and methodologies in PLE makes learning less efficient in the students' self-regulated learning process [61][62]; in addition to, limiting their effectiveness of SRL.

13.3 Opportunities that learning technologies have brought to SRL context

Although there are many concerns regarding technology use in SRL, we cannot deny that the role of technologies have great potential important in helping students with

the transmission and retention of the knowledge[65]during SRL process. By accessing different sources of information, Simao et al. (2008) find out that technology involves new ways of planning and accomplishing learning tasks, which can result in the development of specific skills.[56] Learners have to be capable of self-regulating their learning process in order to achieve the goals they established or that were established for them. On the other hand, teachers should encourage social and intellectual environments which promote self-regulated learning.[59]

Many academic articles and reports seem to hold the same view. It has been shown that learning technologies can serve as an important determinant in fostering self-regulation.[59][65]In fact, the last part of this paper will provide several technology examples on recent student experiences with learning technologies in SRL. The review is intended to demonstrate the effectiveness of learning technologies tailored engage students' self-regulation in the context of self-regulated learning. Specially, when learning technologies are deliberately used to support self-regulation, motivation, and engagement in online learning contexts, students' academic performance will significantly improve towards learning.[65]

In addition, the incorporation of learning technology to support self-regulated learning had been addressed by some researchers, teachers, colleges, and universities. They wish to discern the role that learning technologies play in self-regulated learning environment. Do learning technologies fit into the education landscape as an alternative mode of teaching and learning or a substantial supplement? Can learning technologies bring opportunities for increased interaction between teachers/students and students/students? How can learning technology develop students' metacognition, motivation, and behaviour to achieve their learning goals in SRL. Additionally, the last part will reveal the role technologies play in self-regulated learning and why incorporating technology is essential for self - regulated learning. Several technologies have been developed to engage students in self-regulation, such as Betty's Brain, MetaTutor, and nStudy. Technologies play a critical role in students' SRL activities, which will allow them to select searching strategies, monitor strategy impact, and critically evaluate accessed information, all to promote metacognitive reflection.[56] This part will describe three specific existing technologies and illustrates their implications on supporting and promoting students SRL.

- **Betty's Brain**

Betty's Brain is a teachable agent system created at Vanderbilt University to support students' self - regulated learning and strategy use [66][67] In Betty's Brain, students first "learn by reading about scientific phenomena" (Roscoe et al., 2013, p.287). [67]Based on the knowledge they gain, they will construct a simplified visual representation of concept maps to represent their understanding and to teach the computer agent character Betty via

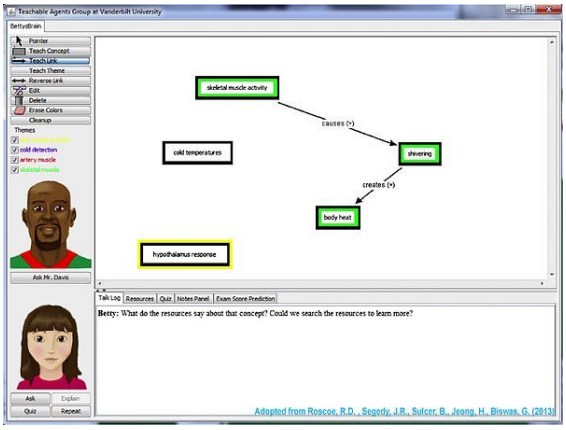

Figure 13. Betty's Brain primary interface

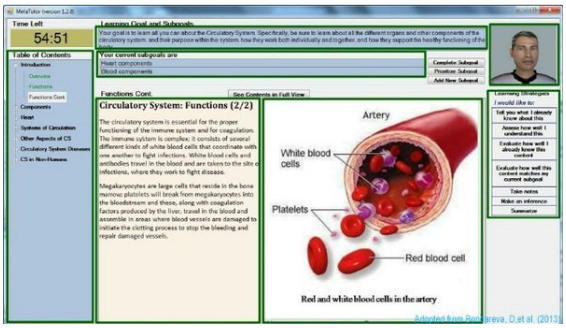

Figure 14. MetaTutor Interface

the concept maps they created.[1] Roscoe et al. (2013) in their article explain how constructing these concept maps can help students to integrate and organize both new and prior knowledge while assisting them in understanding "how individual concepts cohere within deeper principles" (p.287). [67]In order to teach someone else, students have to learn and solve the learning problem first. When learning by teaching, students receive feedback from the Betty program and are motivated to transfer knowledge from one context to another, which results in greater metacognition and self-regulating practices. [66][68] In this way, they will be able to monitor themselves and teach their agent to perform better. In the end, Roscoe et al. (2013) summarize that students can finally "apply metacognitive processes to detect and repair map errors to improve accuracy and completeness" (p.289) by using Betty's Brain.[67]

- **Azevedo's MetaTutor**

According to Khosravifar et al. (2013), MetaTutor is a research-based learning tool for improving students' academic performance. By applying different interactive and strategic intellectual techniques, students will better self-regulate their cognitive, affective, metacognition, and motivation in learning processes [69]. MetaTutor is designed to train and foster high school and college students' learning about complex and challenging science topics through hypermedia [70][69][65]MetaTutor

detects, models, traces, and fosters students' self- regulated learning about human bodily systems [70], which is mainly based on cognitive models of self-regulated learning.[71][72] All the users required by MetaTutor to complete the training session on SRL processes before they begin to explore and access the content on the hypermedia learning environment. There are four pedagogical agents in the hypermedia learning environment, which not only provide feedbacks to scaffold participants SRL skills and content understanding, but also help participants to navigate the system, guide them setting appropriate goals, monitor their progress toward their learning goals, and deploy SRL cognitive strategies such as summarizing and note-taking[65][69][70].

By using MetaTutor, students can interact with different agents and enact specific SRL learning processes by their personal preference.[65][69][70] MetaTutor can track all participant interactions and record user behaviours in a log file. When the data show that a student is using ineffective strategies, the agent might provide feedback by alerting the student to use a better learning strategy. The students could use the feedback from MetaTutor to improve their own learning choices and outcomes in the learning environment [69][70]. At the same time, teachers can collect data from MetaTutor to gain a greater understanding of how students interact with MetaTutor and their learning experiences in self-regulatory processes[69]. Although pedagogical agents in MetaTutor cannot control students overall learning progress in the learning environment, they still provide useful learning strategies to help students and teachers in planning and monitoring.

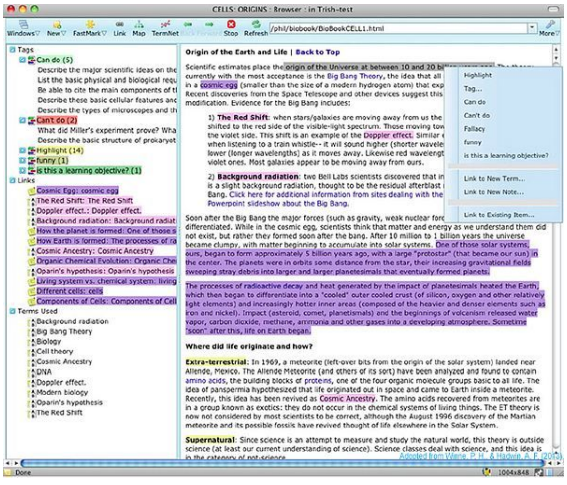

Figure 15. nStudy browser, table of quotes, and linking tools

- **nStudy**

Professor Winne and his research team have designed nStudy, a web-based learning tool, for learners to search, monitor, assemble, rehearse, translate [73] [74] during their self-regulated learning process. The design of nStudy allows both learners and researchers to be active in their learning and researching through a web-based learning environment. In nStudy, they can organize their learning objects by creating, manipulating, and linking them as needed, to help themselves achieve their learning goals. [73][74] As with Betty's Brain, they can also build learning concept maps and then link, group and spatially arrange them. Linking allows learners to create their personal learning network of data and structure the information in their own way, which can be optimal for them to improve their skills in interacting, elaborating, and managing information.[73][74]

nStudy provides both individual and group learners a workspace for them to collaborate, exchange information, and discuss content online, which can create opportunities for them to contact each other to support their collaborative learning.[71] In addition, the ability to exchange information across workspace can be "structured by roles and prompts create opportunities for students to self-regulate, to co-regulate each other's work, and to share regulation" (Winne & Hadwin, 2013, p.302). [71]As learners and researchers use nStudy's tools to study or research, the system collects trace data can reflective of particular cognitive and metacognitive events during their self-regulated learning[71]

14 Facilitating and Encouraging SRL

Self-regulated learning (SRL) is a process that assists students in managing their thoughts, behaviors, and emotions in order to successfully navigate their learning experiences. This process requires students to independently plan, monitor, and assess their learning.[75] SLR is an important predictor of student academic motivation and achievement. The construct of self-regulation refers to the degree to which students can regulate aspects of their thinking, motivation and behaviour during learning. In practice, self-regulation is manifested in the active monitoring and regulation of different learning processes. [76]

Self-regulated learning is not asocial in nature and origin. Self-regulatory processes often develop gradually within an environment that balances structure with opportunity for autonomy. [77] Research shows that self-regulatory processes are teachable and can increase students' motivation and achievement. Each self-regulatory process can be learned from instruction and modeling by parents, teachers, coaches, and peers.[2] In addition, numerous studies reveal that Interventions and trainings on self-regulated learning can enhance students' academic performance [78][79][80] [81] In a study of high school students, Labuhn et al. (2010) found that learners who were taught SRL skills through monitoring and imitation were more likely to elicit higher levels of academic self-efficacy (i.e., confidence) and perform higher on measures of academic achievement compared to students who did not receive

SRL instruction. [82] Accordingly, students should practise self-regulated learning throughout their whole school career, and teachers need to cope with the task to foster their students' self-regulated learning behaviour.[83]

By teaching students to be more self- regulative, teachers may experience greater success in promoting academic achievement, motivation, and life-long learning. [84] Teachers can help students become self-regulated learners who can use effective strategies to help them to make plans and set goals for a learning task, monitor the learning process, and evaluate learning performance with a view to improving it next time. Teachers can promote self-regulated learning in classrooms either directly by teaching learning strategies or indirectly by arranging a learning environment that enables students to practice self-regulation.[85]

14.1 Developing Self-Regulated Learning

According to Zimmerman (2002) [2], self-regulated learning process can be divided into three distinct phases:

Forethought and Planning Phase involves analyzing the learning task and setting specific goals toward completing that task. In this phase, teachers instruct students on effective approaches, provide structured and explicit instruction, model and explain the strategies, and help students to generalize the strategy to other similar learning tasks. [75][77][86]

Performance Monitoring Phase includes employing strategies to make progress on the learning task, monitoring the effectiveness of the strategies, and monitoring motivation for completing the learning task. Teachers can organize activities, provide close monitoring and specific feedback to help students learn to use new strategies. As students learn how to execute the strategies independently, teachers gradually fade instruction and transition into the role of guide.[75][77]

Reflection on Performance Phase focus on evaluating performance on the learning task, and managing emotional responses related to the outcomes of the learning experience. Teachers can provide support by encouraging peer evaluation and reflection, facilitating assessment, and continually relating findings back to the learning goals. Teachers should also prompt students to share what worked well during the learning process, contribute to student self-efficacy and motivation, and provide praise focused on their efforts and use of effective strategies.[77]

Self-regulatory skills are not automatically acquired. The developmental stages of self-regulatory skills consist of four levels: observation, emulation, self-control, and self-regulation. Observation level skills are acquired through modeling which provides learners with an image of successful performance. This helps students establishing general performance standards and conveys a strategy to control motivation during the process of acquiring a skill. On the emulation level, students perform a skill using a general strategy learned through modeling, while teachers' feedback and guidance are critical to improve accuracy of performance. In addition, social reinforcement, such as praise or encouragement, also increases students' motivation. Self-control level involves structured practice and self-observation. Students practice a skill in structured settings on their own. Students may refer to and internalize a model's performance, and should focus on process rather than outcomes. Self-regulated level skills are perform in unstructured settings. Student should focus on effectiveness or quality of performance rather than mere execution of a learned skill, and adjust their performance according to personal and environmental conditions. They can perform skills independently, but still need social support occasionally.[87] Figure 16. shows the cycle of SRL.

Figure 16. The Cycle of SRL

14.2 Self-Regulated Learning Strategies for Students

Types of Self-Regulated Learning Strategies

There are four types of SRL Strategies that can facilitate learning[88][89]: Cognitive strategies include rehearsal, imagery, elaboration and transformation or organization of materials. Elaboration helps students to connect new material to the prior knowledge; imagery refers to mental pictures that students form to enhance their memory; rehearsal helps students sustain information in their working memory; transforming and organizing strategies include summarizing, outlining, note taking or rearranging materials to make learning easier.

Metacognitive strategies include planning, self awareness and monitoring, and self-evaluation. The most important planning strategies are task analysis and goal setting. Commonly used monitoring strategies are self-recording and self-experimenting.[87] Self-testing is a strategy associated with self-monitoring and self-evaluation. Self-instruction and attention focusing are strategies to monitor or control attention. Self-instruction helps students to focus on a task and enhance their encoding and retention of materials. Attention focusing is used to eliminate distraction in order to concentrate on a task.

Management strategies are used to create the optimal learning conditions, which include control of learning environment, time management, and help seeking. Self-recording is generally used to improve time management skills. Encouraging students to ask questions increases students' help seeking behavior. The structure of the classroom, including feedback and interaction, also affects students' help seeking.

Motivational strategies help students enhance and sustain their motivation to engage in academic tasks. Examples are the formulation of a learning objective, which enhances the goal orientation; the development of a positive style of attribution, which enhances the student's self-efficacy; interest enhancement which manipulate materials to make them more interesting or challenging; and self-talk which refers to verbal self-encouragement.

Table1. Types of Strategies:

Teach Student SRL Strategies – Develop Self-Regulated Learners

Teachers play a principal role in developing students' capacity for self-regulation. To promote SRL in classrooms, teachers must teach students the self-regulated strategies that facilitate learning. The most common and effective SRL strategies include: goal setting, planning, self-motivation, attention control, flexible use of learning strategies, self-monitoring, appropriate help-seeking , and self-evaluation.[75]

Goal Setting: Establishing personal goals helps students focus on practical and specific actions that they can undertake to improve their learning. Short-term attainable goals are often used to reach long-term aspirations. Setting proximal goals can enhance self-efficacy and skill development [87]. Teachers should encourage students to set short-term goals to help them tracking their progress, thinking about what they expect to learn and to be able to do.

Planning: Planning can help learners establish well thought goals and strategies to be successful. Teaching students to approach academic tasks with a plan is a viable method for promoting SRL. Teachers can explore with students their plans for reaching the goals they set. Students can then use the plan to remind themselves of the steps and procedures to accomplish the goals and to make any needed adjustments.[75]

Self-Motivation: Students' behaviors regarding choice of tasks, as well as their effort and persistence in academic tasks, are directly related to their intrinsic motivation. Students with high intrinsic motivation are more likely to use metacognitive strategies. Intrinsic motivation may be enhanced by increasing perceived autonomy, perceived competence, and task mastery goal orientation. Stressing the importance of the learning process, providing choice and allowing opportunities for self-direction can enhance intrinsic motivation by increasing the feeling of autonomy.

Attention Control: Self-regulated learners must be able to control their attention. Teachers can help students control their attention by removing stimuli that may cause distractions, and providing students with frequent breaks to help them build up their attention spans.[75]

Flexible Use of Strategies: Successful learners are able to implement multiple learning strategies across tasks and adjust them as needed to facilitate their progress. By modeling how to use new strategies, organizing the classroom to support the related activities, and providing appropriate scaffolding as students practice, teachers can help learners become independent strategy users.[75]

Self-Monitoring: Strategic learners assume the ownership for their learning and achievement outcomes. Teachers can encourage self-monitoring by having students keep a record of the number of times they worked on learning tasks, the strategies they used, and the amount of time they spent on working. This practice allows students to visualize their progress and make changes as needed.[75]

Help-Seeking: Self-regulated learners rather frequently seek help from others when necessary. Classrooms with mastery goal orientation encourage students to ask for help without feeling embarrassed. Teachers can promote positive help seeking behaviors by providing students with on-going progress feedback and allowing students opportunities to re-submit assignments after making appropriate changes.[75]

Self-Evaluation: Teachers can promote self-evaluation by helping students to monitor their learning goals and strategy use, and make changes to those goals and strategies based on learning outcomes. Self-evaluation activities can include using checklists, summarizing learning content, developing and responding to self-questions, and seeking feedback from peers[75]. Figure . shows the basic concepts and corresponding actions regarding SRL.

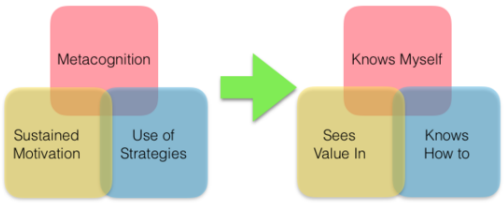

Figure 17. Facets of SRL – concepts and corresponding actions.

14.3 Promote Self-Regulated Learning in Classroom

Instructional Strategies for Encouraging Self-Regulated Learning

Teachers' instructional techniques can enhance students' motivation and promote self-regulated learning. Kobayashi (2006)[89] described four principles for in-

structors to embed SRL in instruction: guide learners to prepare and structure an effective learning environment; organize instruction and activities to facilitate cognitive and metacognitive processes; use instructional goals and feedback to present student monitoring opportunities; and provide learners with continuous evaluation information and occasions to self-evaluate.

- Direct instruction and modeling

Being explicit about how to use different learning strategies helps students to develop a suite of tools they can draw from as they work through the learning. Direct instruction of SRL involves explicitly explaining different strategies to students, as well as how to use those strategies. This kind of instruction focuses on modeling and demonstration; it can be the best initial strategy for encouraging students to be more self-regulative.[75]

Teachers can act as role models in applying a strategy and verbalizing thought processes, or activate students to engage in strategic behaviour by asking questions. For example, in language classes teachers can show a text on the screen and tell students their thoughts about it as they read through it, pausing for questions and comments, such as: "Is this making sense? What's the main idea here? I think I need to go back to the beginning of this paragraph to re-read so that I'm sure I understand." Similarly, teachers can model the writing process by thinking aloud as they write on the board. The self-questions and comments might be: "Am I expressing my ideas clearly? Will my readers understand what I'm trying to say? Am I following my plan or outline? If not, do I need to make a new plan?" During the reading or writing process, students can make notes recording their reactions to indicate their understanding of the main idea, their questions about the learning contents and their personal opinions. On the other hand, teachers can explicitly tell students about a certain activity, by explaining how this strategy improves learning performance, and telling students how to employ, monitor, and evaluate this strategy [85]. In primary classrooms, teachers can use dialogue to encourage students to share their ideas, by asking questions such as "What do you think? " "Why do you think that?" They can also provide explicit instruction on collaborative skills and communicative behaviours that support shared meaning making [90]

- Guided and Independent practice

Guided practice is another way teachers can help improving SRL and motivation. During guided practice, the responsibility for implementing the learning strategy shifts from teachers to students. Student-teacher conferencing is one-way teachers can help students in setting goals and monitoring their strategy use and progress. Independent practice should follow guided practice. During this process, students are given opportunities to practice the strategy on their own, which can ultimately reinforce autonomy.

Teachers should provide students with opportunities for self-reflective practice that improves their skills to monitor, evaluate, and adjust their performance during the learning process.[89] The strategies include asking open-ended questions, requiring students to provide reflection, summarizing the key points of the learning content, and providing opportunities to discuss and answer their questions.[91] For example, to increase SRL and reading achievement in language classes, teachers may request students to record titles of books they have read, record and graph minutes and pages read in reading log, set milestones for systematically increasing challenge level of book selections, and give weekly reflections in reading log.

Teachers should encourage students to practice effective strategies on a variety of learning tasks on an ongoing basis. This helps to promote both generalization and maintenance of the strategy, facilitates students to rehearse the use of strategies, develop ways to monitor and evaluate their performance, and actively engage students in the modification and construction of new strategies.[86]

- Social support and feedback

Social support from teachers and peers can serve an important role as students are learning to be more self-regulative. Often, social support comes in the form of feedback. Labuhn et al's. (2010)[82] research indicated that students who received feedback from their teachers were more likely to accurately use SRL strategies to improve their mathematics scores. Effective feedback includes information about what students did well, what they need to improve, and steps they can take to improve their work. Teachers' feedback helps students to evaluate progress and assess their internal constructions of goals, criteria and standards. [92] Teachers should provide formative assessments that not only show students how they are doing, but also help them learn how to generate internal feedback and monitor their own progress. [93] According to Nicol and Macfarlane-Dick's (2006)[76], effective feedback should: clarify what good performance is; facilitate the development of self-assessment in learning; deliver high quality information to students about their learning; encourage teacher and peer dialogue around learning; encourage positive motivational beliefs and self-esteem; provide opportunities to close the gap between current and desired performance; and provide information to teachers that can be used to help shape teaching.

Teachers play a significant role in the development of effective self-assessment which is a metacognitive skill connected to students' attributions of success and motivation.[90] To promote SRL, teachers can engage students into the assessment process, by clearly defining the measurable and attainable goals set with students' input, modeling and accounting for goals, and adjusting and dif-

ferentiating questions to match students levels.[91] Active involvement of students in the learning process can contribute crucially to constructing a positive learning climate. In higher education, a useful way to facilitate SRL is setting up an interactive forum on the course website, where students can discuss the course material and learn from each other, thereby enhancing the student-centered learning.[94]

- Other instructional strategies

Self-observational technique is a tool for increasing student awareness in SRL. Self-recording can increase student's awareness of the errors they made, so that appropriate strategies could be developed and implemented. Graphing is an helpful method that help students develop the belief of control over the learning. One example is plotting grades and writing down the learning strategies used to achieve these grades to highlight the link between the strategies used and the performance outcomes.[95]

Reflective practice is an important and effective tool for teachers to adapt and revise pedagogical styles to accommodate students' needs. This practice enables teachers to investigate the possible reasons that explain the effectiveness of a given instructional strategy. Through thoughtful reflection, experimentation, and evaluation, teachers can better create meaningful learning experiences for students.[75]

Classroom Environment that Facilitates Self-Regulated Learning

An important approach to fostering SRL is arranging a supportive learning environment, which is made of student and teacher characteristics, the learning contents and tasks, and the teaching methods. Suitable learning environments can enable and encourage students to learn in a self-determined way[85]. Young (2005) [96] described the following guidelines to increase students' motivation and foster SRL in classrooms, i.e., giving positive feedback that supports the development of competence and task mastery orientation, providing activity choice to support the development of self-determination and autonomy, encouraging social connections in learning, and providing feedback on learning performance for promoting motivation.

Students' motivation can be significantly influenced by perceived learner control in the classroom, and by the way of teachers' feedback. A classroom environment with high task autonomy, together with positive feedback in an informational style, will maximally increase intrinsic motivation. Teachers should maintain an optimum balance of learner and teacher control in classrooms, and provide effective feedback. Students are more likely to take challenging tasks when teachers provide specific and qualitative feedback frequently and deemphasize the importance of grades. Participating meaningful activities, having choice of task and working cooperatively can help students in increasing self-efficacy[89]

Teachers should promote a culture of generosity and respect for individual views, such as promote help seeking, help giving, and negotiation of different views, through the development of positive and supportive learning environments. This involves encouraging positive feelings towards challenging tasks, understanding mistakes as learning opportunities, acknowledging and responding to negative emotions connected to learning experiences, and helping students retrain helpless beliefs.[90]

Activities to Foster Self-Regulated Learning in Classroom

There are various type of activities that can promote SRL. Complex collaborative activities promote students' monitoring of their own performance and the others' task-related activities. It helps students to plan actions, formulate ideas, check progress against goals, and reformulate understandings on the basis of group contributions. Meaningful tasks (i.e., tasks relate to students' past experiences, their interests, and have real implications for their learning) can promote motivation and foster SRL. Activities that include cognitive demands targeting individual zones of proximal development are associated with SRL as well. Multidimensional tasks allow student to find comfortable levels of challenge. Playful activities can provide engaging opportunities for self-regulation in primary classrooms.[90]

Paris et al. (2001)[97] described four types of principles that teachers can use to design activities in classrooms to promote students' SRL, which include self-appraisal that leads to a deeper understanding of learning; self-management of thinking, effort, and affect that promote flexible approaches to problem-solving; self-regulation that can be taught in diverse ways; and self-regulation that is woven into the narrative experiences and the identity strivings of each individual.

To help students in becoming self-regulated learners, teachers can create opportunities for students to share information in pair-work and group-work and transfer what they learned; organize open-class discussion about objectives and learning strategies; provide pre-learning activities to establish and share objectives, and post-learning activities to further practice strategy use and consolidate knowledge acquisition; and create reflection moments at the end of class for students to reflect about what they learned.[98] Teachers can also use questionnaires such as the Motivated Strategies for Learning Questionnaire (MSLQ) or Learning and Study Strategies Inventory (LASSI) to give students feedback on their motivation beliefs and learning strategies.[99]

Following are some examples of specific activities that teachers can incorporate into classroom to facilitate SRL: "Think-Pair-Share" activity allows students to reflect on questions, discuss responses with a partner and share thoughts with whole class. "Retrieval Practice" aids in self-observation and promotes meaningful, conceptual, and long-term learning. "Sorting-Chunking-Organizing

Information" activity helps students to organize concepts and terminology to make sense from information. "Reading Reflections" can help students with self-monitoring and reflective thinking. "Exam Wrappers" activity prompts students considering the strategies they used to prepare for the test, and reflecting on the effectiveness. [100]

Action Control: Ability to control action (e.g. motivation, concentration) that help an individual self-regulate.

Cognitive Modeling: Procedure for developing students' performance that involves giving a rationale for the performance, demonstrating the performance, and providing opportunity of practice.

Cognitive Processing: A term used to describe thinking and applying knowledge.

Collaborative learning: sharing and learning knowledge through peers/groups.

Critical Thinking: A type a reflective thinking consisting of weighing, evaluating and understanding information.

Forethought Phase: Strategies taking place before learning. Self-assessment, goal setting and strategic planning.

Metacognition: Thinking about thinking; awareness and understanding of one's thought processes.

Metacognitive Knowledge: Declarative knowledge such as language and memory.

Metacognitive experiences: What the person is aware of and what she or he feels when coming across a task and processing information related to it.

Metacognitive skills: Deliberate use of strategies (i.e. Procedural knowledge) in order to control cognition.

Motivation: Behaviours and thoughts that drive individuals to perform.

Performance Phase: Strategies taking place during learning. Strategy implementation, and strategy monitoring.

Purpose of Engagement: The self-process, the purpose, and the possible actions that are relevant in a specific situation.

Relativist: Knowledge is flexible and changeable. It can be questioned.

Self-Efficacy: How the individual perceives own abilities and the level of confidence for achieving goals from the perceived abilities

Self-Evaluation: Evaluating self according to a standard

Self-Regulated Action: The means by which regulation is conducted.

Self-Regulated Learning: Ability to control and explicitly understand all aspects of one's learning.

Self-Regulated Phase: Strategies after learning has taken place. Evaluation.

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