Abstract: - Self-Regulated Learning (SRL) is an established educational psychology track of expertise and research. In SRL, learners carry out large extent of the learning process independently utilizing different forms of regulatory processes. From systems and control engineering (technical cybernetics), SRL can be viewed in terms of a closed-loop system. In this paper, a cybernetics model of SRL is proposed and furthermore, a mathematical model of SRL is developed. This is probably the first time where a cybernetics and mathematical modeling is developed for SRL.

Key-Words: - Systems and Cybernetics, Self-Regulated Learning, Mathematical Modeling, Engineering the Education.

1 Introduction
Self-Regulated Learning (SRL) is an educational psychology theory that has emerged to research best models and practices to achieve enhanced students’ autonomy and self-regulation during the learning process. The SRL term was first proposed in the mid-1980s ([1]). Consequently, research studies were published defining the field further, proposing models and evaluation instruments and verifying through empirical research ([2]; [3]; [4]; [5]; [6]; [7]; [8]). SRL is defined as a “Proactive process that students use to acquire academic skills such as setting goals, selecting and deploying strategies, and self-monitoring one’s effectiveness, rather than as a reactive event that happens to students due to impersonal forces” ([1]). In looking from systems and cybernetics perspective, many similarities between SRL and the classical closed loop controlled system can be notified. In this paper, these similarities have been utilized to map SRL into a cybernetics closed loop system. Furthermore, mathematical models have been developed for the process of SRL.

2 Literature Review on Self-Regulated Learning
Literatures show that SRL is not only a single personality trait that individual students either possess or lack [9]. Instead, it involves the selective use of specific processes that must be personally adapted to each learning task, where instructors can teach in ways that help students become self-regulated learners and even learn to be more self-regulated [10]. SRL has also defined as “an active constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and the contextual features of the environment” [11]. According to literature [12], SRL involves self-monitoring and self-correction of three learning components: motivation, behaviour, and cognition. This refers to active learning process oriented by three important aspects of learning: (1) motivation to learn; (2) meta-cognition (awareness of one’s knowledge & beliefs); and (3) strategic action (planning, evaluating, and acting) [13]. Literatures have showed that SRL has a positive impact on students’ academic achievement and attainment [14], [15]. The self-regulation process can be enhanced by mentoring and utilization of effective strategies [16]. Students can be trained to acquire SRL skills and strategies such as: setting goals, planning, management, self-evaluation, and assessment along with the learning path. Self-regulated learning is particularly appropriate for college students as they have a great control over their own time schedule and how they...
approach their studying and learning goals [17]. According to Zimmerman [18] Self-regulation refers to “self-generated thoughts, feelings and actions that are planned and cyclically adapted to the attainment of personal goals”. SRL includes processes such as: “setting goals for learning, attending to and concentrating on instruction, using effective strategies to organize, coding and rehearsing information to be remembered, establishing a productive work environment, using resources effectively, monitoring performance, managing time effectively, seeking assistance when needed; moreover, holding positive beliefs about one’s capabilities, the value of learning, the factors influencing learning, and the anticipated outcomes of actions, and experiencing pride and satisfaction with one’s efforts” [19]. Another definition of SRL has been proposed by Schunk and Ertmer [20]: “the degree to which students are metacognitively, motivationally and behaviourally active participants in their own learning process”. Some SRL researches [20] aim at answering questions such as: “How do students become masters of their own learning processes?”. Schunk and Ertmer [20] indicate that students can self-regulate their motivations, goals, learning processes, and the knowledge resources. Zimmerman [21] emphasized that Self-regulation is not just concerned with ‘thinking skills’; it also has a concern questions about the role of motivation, emotion, and self-concept in the learning process. Wolters [22] emphasized on regulating motivation as a core aspect of self-regulation, while Pintrich [23] emphasized on goal orientation. Zimmerman [19] model, shown in Figure 1, represents the cyclic nature of SRL, which as will be illustrated later in this proposal, can be captured through a control systems feedback loop.

Studies of the use of learning strategies have shown their positive impact on producing better learning outcomes ([19]). It has been found that SRL skills can be generally learnt even by low-capability students [24]). Training the students to use SRL techniques could reduce pressure on teachers’ time and foster the concept of life-long learning.

3 Systems and Cybernetics Concept for SRL

Control systems have been the nerve of industrial innovations in the last century [25], its methods have been also applied to other disciplines such as biology ([26]; [27]), economics ([28]), finance ([29]), policy ([30]), management ([31]), physics ([32]) and psychology ([33]). Control systems methods are much less used in pedagogy ([34]; [35]). In this section, we provide an analysis whereby SRL can be viewed from control systems perspectives. There are a few common and distinguishing components of SRL models: goal setting, learning strategies, monitoring and feedback. In comparison with the standard feedback control systems loop, shown in Figure 2, goals are the reference signals (R), learning strategies are the controller, monitoring and feedback is the sensors. The adoption of learning strategies is explicitly referred to as the control component of Pintrich’s model of SRL [11]. Puustinen and Pulkkinen [36] conducted a review of SRL models that are emerging and empirically valid; they noticed that SRL models are classified either as goal-oriented processes in the work of Zimmerman et al. [37], Pintrich [5] and Boekaerts et al. [7], or as a process dominated by metacognition in the work of Borkowski et al. [38] and Butler and Winne [4]. Indeed, if one looks at SRL from a control systems perspective, both goal orientation and metacognition are fairly important for the process to achieve its aim [39]. Metacognition refers to the learners’ ability to self-evaluate their progress and also to choose tactics and strategies that suit a learning or skill acquisition...
phase. This is relevant to the sensors, comparison, and controller components in the closed control loop system shown in Figure 2. If any of these components fail, the system will fail [39]. Without a clear reference (goals), the process will lose its way, even if the other components are well designed and work properly [39]. When the student is able to establish and deploy all the components and signals of the closed loop system shown in Figure 2 (goals, controller, process, sensors, evaluation, and outcome); this can be called perfect SRL [39]. Mathematical modelling of perfect SRL has revealed the attainment of stable and convergent learning outcomes [39], it is aimed to verify this hypothesis empirically and to build over the presented analogy between control systems and SRL throughout this track of the project proposal. Learning technologies will be investigated as tools for implementing SRL components.

![Feedback control system representation of a learning process.](image)

**Figure 2.** Feedback control system representation of a learning process. The controller can be the teacher, the process can be the student’s learning and the sensor represents the assessment of actual learning outcomes. Evaluation of the discrepancy between the learning outcomes and actual learning is fed to the controller to act accordingly to reduce the gap.

### 3 Mathematical Systems Modeling of SRL

Mathematical models are not popular in pedagogical research; however, they provide a powerful tool for analysis and design. We argue that a perfect self-regulated learning process can be modelled as follows:

$$\frac{dx}{dt} = -a' x + r$$

(1)

where $x$ is an internal state representing the actual learning level (already constructed knowledge), $r$ is the learning objective (goal) and $a'$ is the learning constant that may differ from one learner to another. On the other hand, we argue that a classical approach to learning (e.g. passive teacher-student model) can be modelled as follows:

$$\frac{dx}{dt} = au$$

(2)

where $x$ represents the accumulated knowledge, $u$ is the teacher’s input that determines the speed of information transmission (in other words, the teaching speed) and “$a$” is a variable that differs from one learning task to another and from one student to another. The model given in equation (1) represents a closed loop integrating process which is stable and robust. Stable means that the output ($x$) is guaranteed to reach the desired value ($r$) and to stabilize around it. Robust means that the process can result in similar outcome despite model uncertainty in relation with the constant ($a$). This implies that lower achieving students (e.g. who have lower value of $a$) can have rather similar outcome to average achieving students. Hence, there are convergent learning outcomes for a set of students of different learning abilities as a result of fostering SRL. The simulations in Figure 3 (right) shows the convergent and stable learning curves of two students of different learning capabilities (average and weak) under a perfect self-regulated learning process. The learning objective is set to (1 learning unit)/(1 time unit) tuned for the capacity of the average achieving student. By the end of the first time unit, one can notice that the learning outcome of the lower achieving student is slightly behind the average student. By allowing more time, the learning outcome of both students will converge eventually. On the other hand, the model given in equation (2) is on the border of stability; hence, any disturbance (e.g. lack of attention) can result in reduced learning outcomes. The model is also non-robust, hence lower achieving students are unable to achieve similar outcome to the average students. Hence, there are divergent learning outcomes for a set of students of different learning abilities. The simulations in Figure 3 (left) shows that the learning outcome of the lower achieving student lacks significantly behind the average achieving students in an open loop learning process, e.g. teacher-student passive teaching approach. The
abstract models in equations (1) and (2) can be used as a basis for modelling a set of pedagogical processes such as PBL ([40]), lecturing ([41]), Kolb’s experiential learning theory ([41]), etc. Structural differences among these processes can be distinguished via different parameters, and different controllers.

4 Conclusion
Self-regulated learning (SRL) is an important aspect of learning and refers to the processes by which individual learners monitor and control their own learning. Students who are self-regulated learners are more likely to be successful, to learn more, and to achieve better. SRL is important for enabling lifelong learning (LLL), a demanded aspect for modern 21st century societies. Efficient SRL skills are particular is important for engineers, who in the majority of cases have to LLL due to the ever-evolving nature of engineering. In this paper, SRL has been approached from Systems and Cybernetics perspective, allowing conceptual and mathematical modeling for a qualitative educational psychology theory. This approach could give a more analytical in-depth understanding of SRL process. Furthermore, the mathematical abstraction could be extended further for systems’ implementation in future work, very similarly to the design of control systems based on mathematical modeling in technical systems.

References:


