Classroom Cybernetics: an Approach for Effective and Efficient Classroom Teaching

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Abstract-Cybernetics is not a new invention but its potential for application has not exhausted even after nearly seventy years of its origin. It started with idea of automation and control in the electrical and mechanical systems, but later on extended to biological, social systems and learning systems. Present paper is about application of cybernetics in education systems and discussion has been limited to only classroom situation. Cybernetics means 'to steer', 'to navigate' or 'to govern' for taking the system to desired goal. Here in classroom teaching-learning process is a system and the goal is success of the learner and learning process. Classroom cybernetics is constituted by Constructivism, Conversation theory and a feedback system. Constructivism resulted in five E's namely- Engage, Explore, Explain, Elaborate and Evaluate. Conversation theory necessitatesinteraction between teacher and learner which passes through three levels of language namely-natural language, subject language and meat language. Feedback is another essential element of cybernetics which is an instrument for controlling the system to maintain equilibrium, move forward or even reverse it. Problem with the conversation theory is that it is applicable only for one to one correspondence between teacher and learner, thus can't directly help in classroom situation. To make it applicable for classroom situation Ashby's Law of requisite Variety has been applied which necessitates that teacher need to be hugely better equipped than the learners and should be skilled enough to visualize the learners' state of mind. Thus effective use of constructivism, conversation theory, feedback loop and Ashby's law of requisite varieties makes comprehensive Classroom Cybernetics.

Index Terms- Cybernetics, Control, Constructivism, Conversation theory, Feedback

The term Cybernetics originated from Greek word κυβερνητική (*kybernetike*), meaning "steer" or "navigate" or "govern" and verb form as κυβερνάω (*kybernao*), meaning "to steer" or "to navigate" or "to govern". Cybernetics began as an interdisciplinary study connecting the fields of control systems. The term Cybernetics was coined in 1947, shot after close of Second World War by a mathematician named Norbert Wiener, while heading a group of scientists working on control and communication theory for achieving automation in machines and electrical networks. It was simultaneously extended to observe in natural/biological systems like evolutionary biology, neuroscience, working of heart, anthropology, psychology and the like. Stafford Beer called Cybernetics as science of effective organization, whereas Pask named it "the art of defensible metaphors" (emphasizing its constructivist epistemology) though he later widened its domain to include information flows "in all media" from stars to brains. It includes the study of feedback, black boxes and derived concepts such as communication and control in living organisms, machines and organizations including self-organization. A more philosophical definition, suggested in 1956 by Louis Couffignal, one of the pioneers of cybernetics, characterizes cybernetics as "the art of ensuring the efficacy of action."The most recent definition has been proposed by Louis Kauffman, President of the American Society for Cybernetics, "Cybernetics is the study of systems and processes that interact with themselves and produce themselves from themselves."

There are two forms of cybernetics having a relation somewhat like method/teaching and methodology/research, in method we solve a problem with its application and in methodology we study about development of method to be used. These are termed as first order cybernetics and second order cybernetics. First order cybernetics is about the observed system and second order cybernetics is about observing the systems. If first order cybernetics is assumed to be physics/physical then second order cybernetics would be metaphysics/metaphysical.
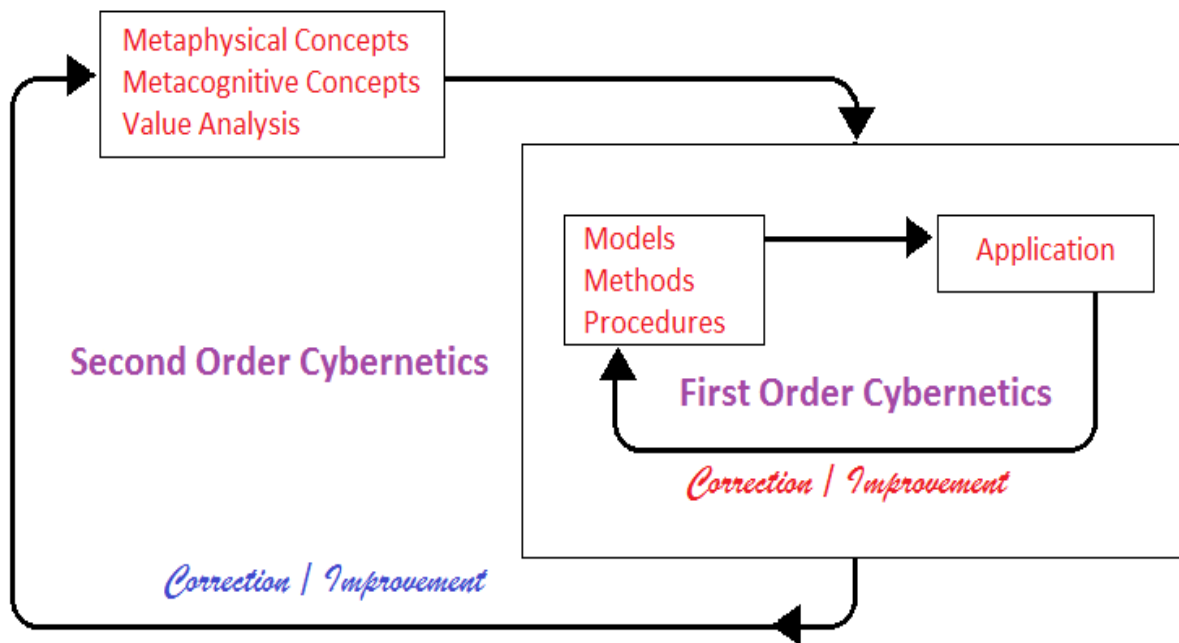
1. APPLICATION OF CYBERNETICS ON CLASSROOM TEACHING

As we have understood that education is a system and classroom teaching is a subsystem of education system. Thus cybernetics can be applied on classroom teaching system to improve it by making it an automated system for improving efficiency. Teacher works to steer to find solution to problem or to reach to the target known to both teacher and learners. We may name this process as for education system as Educational Cybernetics and for classroom teaching as Classroom Cybernetics. In this paper we will basically limit our discussion to Classroom Cybernetics. Let us elaborate the components of process of Classroom Cybernetics.

Classroom Cybernetics is based on three concepts namely- Constructivism and Conversational theory and Feedback. We must understand these concepts for understanding how this work in an integrated form we call as Classroom Cybernetics.

1.1 Constructivism

Thesis of theory is "Knowledgelies in the heads of an individual" and one constructs meanings/knowledge based on one's own experience rather than as perceived by anybody else. That is why one produces unique sense to a concept in the learning domain. It seems to be true also in classroom situation. When a teacher teaches a

group of students in the class, not all the students are taking in every bit of content being presented by the teacher. It means learner 'takes in' the content selectively and associates it with already available stock of related knowledge, thus creates unique meaning to the concept being taught. As experiences are subjective and unique to every individual thus knowledge is also unique to every individual. The experience and interpretation of language is one and the same thing in the context of constructivism.

Origin of constructivism can be attributed to ideas of Lev Semyonovich Vygotsky (1896-1934), Jean Piaget (1896-1980) and Maria Montessori (1870-1952). Vygotsky believed that learning is resultant of one's interaction with his/her environment and its exploration. Environment includes both living as well as non-living. His theory of cognitive development included three important but interactive aspects- Social Interaction (SI), More Knowledgeable Others (MKO) and Zone of Proximal Development (ZPD). SI is about necessity of social interactions for learning, MKO emphasizes that child can learn better when s/he interactions with more knowledgeable persons and ZPD implies that at specific points child needs some help from a more knowledgeable partner in the form of scaffolding. Thus Vygotsky gives importance to relation, communication

and better knowledgeable partner may be a person (senior or teacher) or a machine (computer).

Piaget believed that children learn through organization and schemas. Schemas are built of ideas and concepts of the child. Child passes through four stages of development namely-Sensory motor (0-2 years), Preoperational thought (2-7 years), Concrete operational thought (7-11 years) and Formal operation thought (12 years and above). At first stage learner knows the world only of his sensory inputs and his/her physical and motor actions are decided on the basis of these inputs. Second stage is marked by intuitive thought, symbols in play, geocentricism and lack of conservation. Child remains self-centered and rejects learning from others. At third stage "logic is still tied closely to concrete materials, contexts and situations" (Littlefield Cook & Cook, 2005/2009). At final stage child attains five higher cognitive abilities namely- hypothetico-deductive reasoning i.e. scientific reasoning, abstract thought, separating reality from possibility, combinational logic and reflective thinking. Although Piaget differed from Vygotsky in terms of stages, but both agree that interaction and exploration of environment is vital for cognitive development.

Maria Montessori states-

"Scientific observation has established that education is not what the teacher gives; education is a natural process spontaneously carried out by the human individual, and is acquired not by listening to words but by experiences upon the environment. The task of the teacher becomes that of preparing a series of motives of cultural activity, spread over a specially prepared environment and the refraining from obtrusive interference. **Human teachers can only help the great work being done, as servant help the mater.** *Doing so, they will be witness to the unfolding of human soul and to the rising of a New Man who will not be a victim of events, but have clarity of vision to direct and shape the future of human society".*

-Maria Montessori, Education for a New World

The Biological Science Curriculum Study (BSCS), headed by Roger Bybeein nineteen eighties developed an instructional model for constructivism, named the "Five Es" i.e. Engage, Explore, Explain, Elaborate and Evaluate. The model is presented in the figure given ahead.
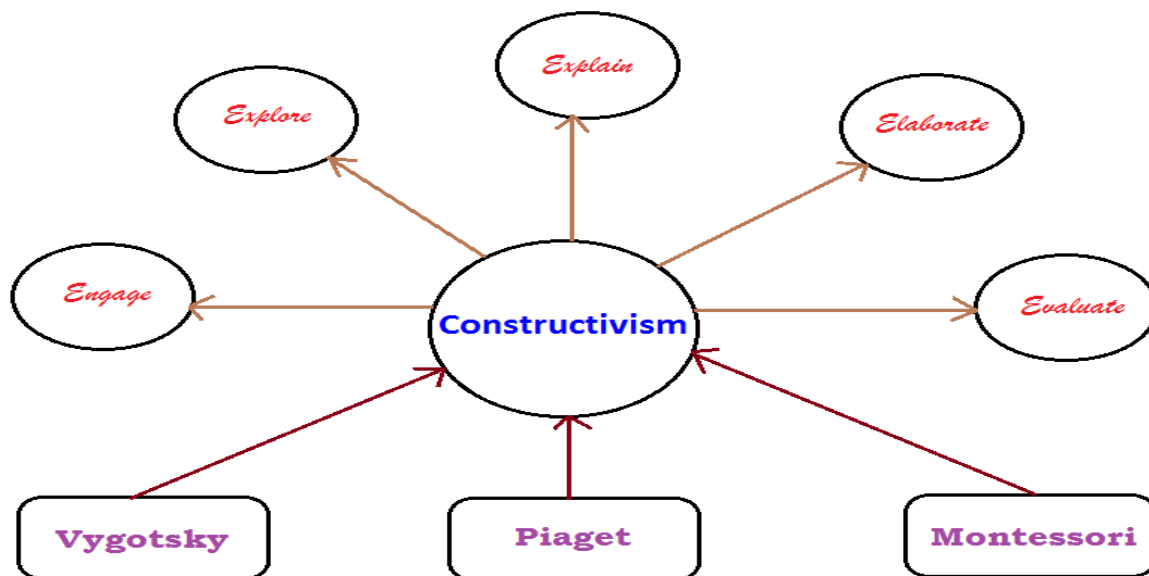
Engage: it is first step which requires student's attention to be arrested for the proposed task, it should promote curiosity and bring prior knowledge to conscious level.
Explore: involves activities that facilitate conceptual change.

Explain: it is about a particular aspect of the concept, learner explains about his/her understanding and teacher may use it for developing deeper understanding.
Elaborate: extending the domain of learning related to concept at hand.
Evaluate: to assess the attainment in respect of goal agreed by the teacher and learner.

International Journal of Research in Advent Technology, Vol.4, No.1, January 2016
E-ISSN: 2321-9637
Available online at www.ijrat.org

1.2 Conversation Theory

Conversation theory was proposed by Andrew Gordon SpeediePask (1928–1996) an English Cybernetician and Psychologist from Engineering and Natural Sciences background. It was an outcome of Pask's work on instructional design and models of learning styles among human beings. His theory was mainly focused on learning and education; however he wanted to implement it on all sorts of issues of physical sciences, natural sciences, social sciences and humanities. As far as learning goes, he proposed three styles of learning namely- *holist*, *serialist*, and their *optimal mixture versatile.* Holists are more creative, look for higher order relations, ready to follow new routes for learning, and may leave some gaps in the knowledge structure, whereas serialists, follow a sequence in a defined manner to find relation in structures, are more organized and have less risk taking behavior. Optimal mixture versatile is a person who has ability to combine advantages of both serialist and holist learning styles. His process of learning revolves around sharing personal reality and reaching the consensus agreement termed as "Conversation". The main objective of conversation theory is "construction of Knowledge". The elementaryidea of Conversation theory is that learning occurs through conversation about a subject matter of concern between two parties which serves to bring knowledge in public domain and make it acceptable. By sharing and building consensus on issues of knowledge human beings construct knowledge.
Conversations occur at least at three levels:
Natural language (general discussion)
Object languages (for discussing the subject matter)
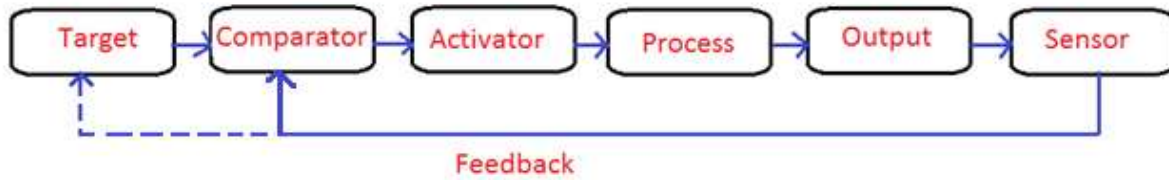Metalanguages (for talking about learning/language)
 Natural language is nothing but a general discussion between two participants involved in the process of learning. However this general discussion is not beyond the general boundaries of the domain of the subjects. This general discussion makes sense for matching of interest, frequency and intensity of the participants (may be two teachers, two students or teacher and learner). The validity of such language can be assessed from the vocabulary, semantics and general validity of the content. As Cybernetics is about conversation between/among persons, machines, bio-systems, social systems and the like, thus natural language in that sense is a general system of communication between two entities.
Object language is actual discussion of the subject matter concerning the objectives of learning. A subject matter of learning always has a purpose and defined target for it. For instance a student learns to appear in examination, score marks and hence to get certified for possession of certain domain of knowledge. In school situation object language is about specified content or syllabus. Object language includes technical symbols, formulae, algorithms, framework, terms, procedures and the like. In case of other than learning systems these can be specific relation between parts of machines or machines of system, parts of a biological system or communication between systems etc. Object language is a step forward towards finding solution to the problem.
Meta language is not about method, rather it is about methodology. In learning it amounts to strategies, methods, models, devices, skills and the like. In bio-systems it is complex level communication to maintain, regulate or restore balance, equilibrium, gradient, flow etc. In case of machines it can be taken as strategy to reduce effort and gain maximum output by virtue of short cuts, route variation, introduction of electronics and communication. And in computers it could be equivalent to software use i.e. high level language instead of low level language (assembly or machine language). Meta language is not operationalization; rather it is planning for operation. Pask suggested "teachback" as strategy for learning according to which a person teaches the partner what s/he has learnt. Teachback involves all the three levels of language required in learning and need to apply both in serialist as well as holist learning styles.

1.3 Feedback

Issue of feedback is an essential element of the concept of Cybernetics. The general meaning of the term "feedback," is 'a system reacting to its own output', originally used in Physics in electrical and mechanical systems. The corollary has been carried out of coining terms like "biofeedback," a technique to monitor bodily processes as a mean of controlling them. Similar more terms could be information feedback in information systems, analytical feedback in manufacturing systems and so and so on. In classroom situation also teacher as well as learner receives information on their respective performance in many ways to improve the efficiency and effectiveness of delivery of the content. Feedback thus helps in maintaining the equilibrium, moving it forward or reversing the direction of the process. A simplest cybernetic system consists of calls a sensor, comparator, and activator (Littlejohn, 2001). The sensor provides feedback to the comparator, which compares with the target and discrepancy is reported to the activator to continue or stop or even reverse the system. This terminology is very much direct representation of an electrical system presented in the figure given below

International Journal of Research in Advent Technology, Vol.4, No.1, January 2016
E-ISSN: 2321-9637
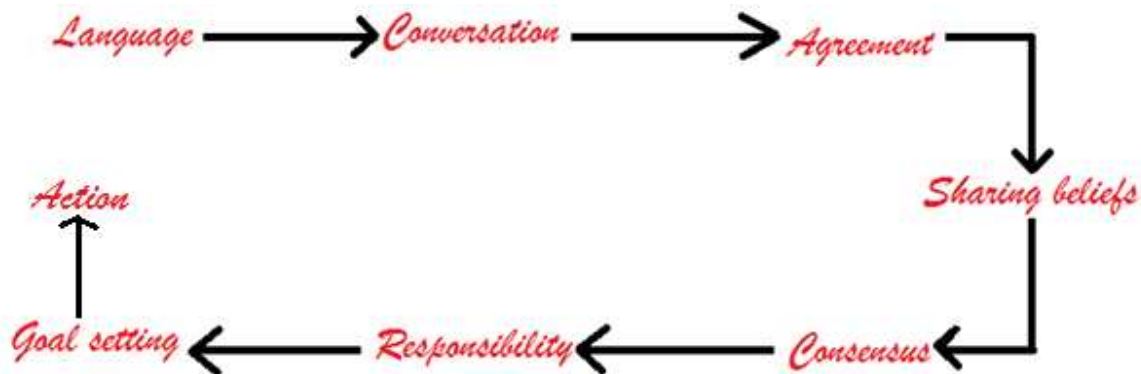*Available online at www.ijrat.org*

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However, some feedback systems are more complex than simple ones. The simplest difference can be considered as direct or indirect feedback, active or passive feedback, quantitative or passive feedback and concrete or interpretive feedback. In all the pairs the former were simple and latter are complex forms of feedback. Further feedback could be forward (positive) as well as backward (negative). Former is to support the action (to repeat the behavior or continue the same behavior) and latter is to stop or reverse the action (to reduce or stop or exhibit the reverse behavior). As per Cybernetics these three are feedback states namely-steady state (equilibrium maintenance), growth state (forward or next level), and change state (backward or reversal). In a steady state when deviation in the outcomes occurs, the system acknowledges a problem, and returns to normalcy to restore the original situation. The growth state is for forward moving and change means stopping or reversing the direction.

2. CLASSROOM CYBERNETICS: APPLICATION OF CONSTRUCTIVISM, CONVERSATION AND FEEDBACK

As per constructivism child must be allowed to construct knowledge through 5 E steps (engage, explore, explain elaborate and evaluate. Construction requires freedom to express experiment and resist the stereotypes. Teacher is expected to support initiatives of learners and should guide to avoid constructions go astray. This guidance is under constructivism is contribution of Vygotsky's SI, MKO, and ZPD summed as concept of scaffolding. Although constructivism advocates for freedom of learner to construct meanings/knowledge (Vygotsky 1962), but at the same time approves presence of teacher in the classroom and beyond. Piaget necessitates use of age appropriate contents for classroom teaching. Content for younger children need to contain colorful material, cartoons and inspirational stories etc. This aspect is very strongly supported by Montessori.

Conversation theory suggests that interaction is necessary for learning to happen. It necessitates passing through three stagesof language (Natural language, Subject language and Metalanguage) for both teacher and learner. Natural language is for building rapport between teacher and learner followed by actual transaction of the subject matter which builds stock of knowledge for further use. Metalanguage is the stage when teacher and learner could imagine the nature, purpose, spirit, structure and sources of knowledgeof a given subject matter. Metalanguage helps the teacher and learner to be a thinker, philosopher and inventor in the fieldif study. Cybernetics operates through following sequence of events for reaching the goal setting and taking action.

International Journal of Research in Advent Technology, Vol.4, No.1, January 2016
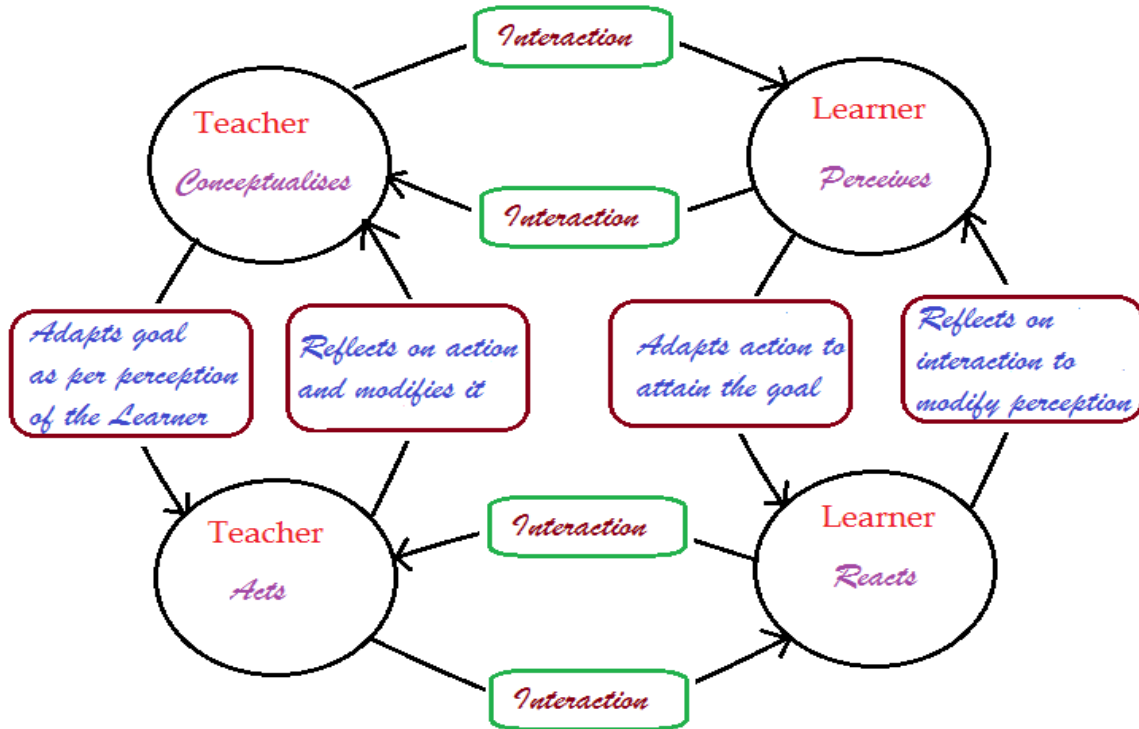*E-ISSN: 2321-9637*
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Problem with conversation theory is that it is imagined as one to one correspondence of teacher and learner rather than teacher and group. This means it requires tutoring or small group teaching instead of bigger classes' scenario. This problem is tackled by Ashby's Law of requisite Variety, which states "If a system is to be stable the number of states of its control mechanism must be greater than or equal to the number of states in the system being controlled" (Ashby,1956). Here students and their learning perceptions/ability are states of the system being observed by the teacher. For teaching to take place teacher must have greater variety/states(knowledge) than students i.e. should be an expert in comparison to all the students. A teacher must be able to visualise what must be going through the minds of different learners. This will help the teacher to modify his/her teaching as per variety/sates of the learners. The learning process in a classroom situation can be presented as follows.
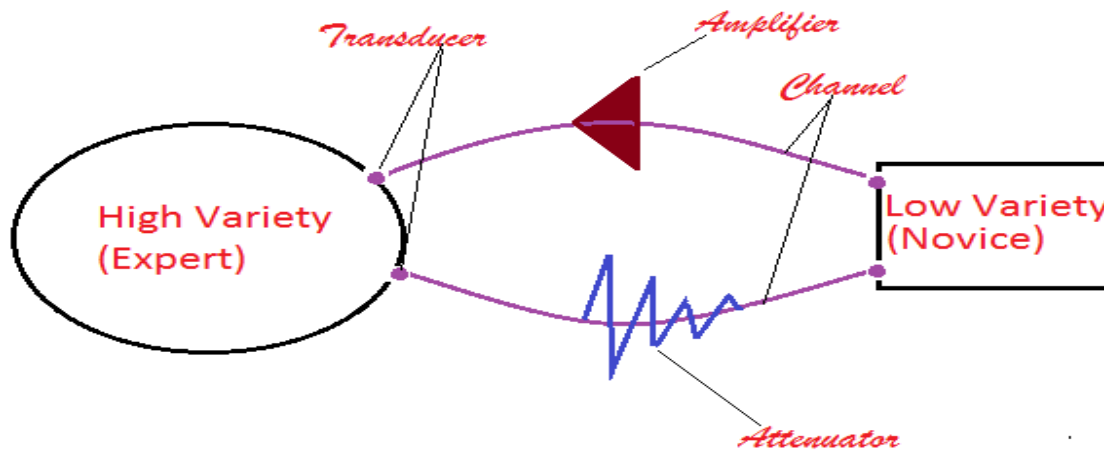
It is a hybrid of classroom situation and an electrical circuit which looks for control and balance. Teacher and students interact where teacher has more variety than the learners. The variety here means that teacher understands what different possibilities are there that learners can seek- answer to questions, doubts, and where they can miss the important points and so and so on. Teacher uses channels (audio, visual, and audio-visual) and transducers (techniques) to make content communicable to the learners. Learners receive the contents and send the feedback, which makes basis for amplifying (increasing) and attenuating (decreasing) the level/amount of the content.

Feedback becomes a very vital part of the Cybernetics in the classroom. Feedback helps in controlling the system and maintaining its balance as well. Feedback can be a simple loop as in case of simple systems (as in classroom only) and may be in the form of multiple loops in case of complex systems. Multiple loops for feedback in school can be in the form of official records, homework, examination records, parents' perceptions, other teachers and the like. The whole Cybernetics of classroom situation can be presented as given in the following figure.

International Journal of Research in Advent Technology, Vol.4, No.1, January 2016
E-ISSN: 2321-9637
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Interactions are transaction of subject matter or feedback channels for conversation among teacher and each learner. There is also interaction between two positions of teacher and learner for controlling oneself along with controlling others. There is always dynamicity in the system which calls for adjustment on the basis of feedback received from other end. In conclusion we can say that Cybernetics calls for

- freedom to learn as per one's own terms i.e. learner must be participant on equal basis in the learning process.
- there must be conversation between teacher and learner/s i.e. teacher student interaction is a must for knowledge transfer.
- a guide (teacher) is needed for guiding the learner to pass through stages of 5E's (engage, explore, explain, elaborate and evaluate) and three levels of languages (Natural, Object and Metalanguage) i.e. teacher must create environment and take learning process through different phases for reaching to conclusion.
- a feedback mechanism by which learning can be controlled to be keep it on the track.

3. CONCLUSION

Although Cybernetics has been an inspiration from nature and biological systems, but it has great potential to be applied on other systems like education and classroom teaching. The basic idea of Cybernetics is automation and control which is best depicted in natural and biological systems. Human beings have always tried to bring perfection in the manmade systems as we see in the nature. Thus classroom Cybernetics is an attempt to apply principles of Cybernetics to improve efficiency and effectiveness of classroom teaching. Teacher plays the role of steer man who navigates through the ocean of problems and takes the learner to the target agreed by both teacher and learner. It is done in a systematic, conscious and professional manner.

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