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A Multi-Disciplinary Cybernetic Approach to Pedagogic Excellence

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Abstract

This paper presents a theory of good pedagogy that i) unifies several current theories, ii) is cybernetic, that is, content independent, and iii) operationally defined. The paper builds off a recent theoretical unification of pedagogy using the four pedagogic pillars of executive function, goal-setting, attribution theory, and self-efficacy. A novelty of the theory is avoidance of jargon, such as higher cognitive, which, while having intuitive appeal, has meaning which is ambiguous. The theory also avoids secondary terms such as creative or analytic and instead focuses on root psychological processes such as executive function and multiple modalities. The theory is applied in a multi-disciplinary setting addressing both machine and human mastery of tasks. This multi-disciplinarity is synergistic allowing simultaneous considerations of emotional (human) and efficiency (machine) issues. The theory is easily applied to new situations without the need for special training. It is hoped that instructors will begin to use this approach in their instructional design.

Keywords: *pedagogy, transdisciplinary, multidisciplinary, learning mastery, executive function, multiple modalities, attribution theory, self-efficacy, educational hierarchies,*

1. Background

This section briefly reviews the history, theory, and philosophy of the pedagogic hierarchies.

1.1 The Pioneering Work

The first characterization of pedagogic excellence was pioneered by Bloom (1956) in the middle of the last century. He introduced the *pedagogic hierarchy*, a list of terms or concepts that describes different pedagogic approaches which are increasing in pedagogic challenge. Bloom introduced a specific six-term hierarchy, starting with a low-challenge pedagogic technique, *remembering* and culminating with high-challenge pedagogic techniques, *evaluation* and *creating*. For the practitioner to properly apply the hierarchy terminology, each item is further

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clarified in terms of a collection of synonyms.

1.2 Multiple Theories

Bloom's pioneering work was complemented by similar attempts of Anderson (2001), Gagne (1985), Marzano (2001), Van Hiele (1986) and many others. Each researcher advocated a different hierarchy or set of stages necessary for learning. A breakthrough was made in the first decade of this century in a ground-making paper showing that teaching by two particular hierarchies had the same effect of improvement thus pointing to an underlying unity(Yazdani, 2008).

1.3 A Unified Approach

Hendel (2017), although his work was theoretical without testing in the classroom, offered a comprehensive unified theory. Moreover, Hendel's proposed unification was based on neuro-psychological concepts pointing to a certain objectivity. A fundamental contribution of this unification is the use of unambiguous terms. For example, *analysis, creative, synthesis,* while having definite meanings may differ in their implied nuances from person to person. Contrastively, Hendel spoke about the use of multiple modalities, multiple areas of the brain; this has a certain objectivity and lack of ambiguity.

1.4 The Four Pedagogic Pillars

The four pillars of pedagogic excellence proposed by (Hendel, 2017) are:

- Executive function (use of multiple modalities)
- Best goal-setting practices (the breaking up of tasks into the sequence of subtasks that is best for mastery)
- Attribution theory, (the realization by instructor and student that success is based on practices internal to the student (no outside influence) and controllable by the student such as effort and work)

• Self-efficacy, (the belief of the student that with his current skill-set he can successfully accomplish a task. Self-efficacy has been shown in numerous areas to be the single most effective predictor of success).

2.Goals

The goal of this paper is to reformulate the above theory in a purely cybernetic multi-disciplinary context. This section discusses the approach of these two areas, cybernetics and multi-disciplinarity, as well as indicates the benefits of considering them.

2.1 Cybernetics

Cybernetics studies complex systems (Ashby, 1956, Weiner, 1948, 1950). Some examples of complex systems might be the human body, or the corpus of knowledge in a course. Cybernetics introduces a terminology that discusses the system performance independent of its content. The following example is illustrative.

> <u>Example:</u> Suppose one was asked about a course of whose content they are ignorant, "How should I construct a syllabus for my course?"
>
> At first blush the question may appear impossible to answer: How can one describe a course syllabus without knowing anything about its content?
>
> Continuing the example, we can illustrate how cybernetics offers content-independent, but nevertheless, concrete advice.
>
> One part of the response might point to *prerequisite sequences:* "Assure that each syllabus topic has had its prerequisites already covered in the syllabus." Such a statement is independent of content but is a valid universal principle by

which any syllabus must be constructed (Hendel, 2023).

Another part of the response might emphasize that each syllabus topic should address multiple modalities of the mind such as *visual, verbal, formal, and computational.* Again, although this rule is independent of content, it points to a good syllabus practice (Hendel, 2015).

2.2 Ashby's Contribution

Ashby (1956), a psychologist and cybernetician, emphasized that in discussing any psychological endeavor, catchy jargon which appeals, but is not well defined, should be avoided. For example, the statements that teaching should be *cognitively demanding, address higher mental abilities*, and similar phrases echo frequent pedagogic advice that satisfies the appetite of educational regulators and reviewers. However, these italicized terms while having intuitive meaning, have ambiguity; each researcher has a different conception of what the phrases refers to.

Thus, a fundamental goal of this paper is to assure that all concepts are clear and without ambiguity. We have already pointed to the paradigmatic example of *multiple modalities.* This principle is clear and lacks ambiguity since *any given* teaching module either addresses one or multiple parts of the mind. Below we show that this principle is also powerful. Despite its simplicity it can accomplish its goals.

2.3 Multi-disciplinarity

Multi-disciplinarity refers to studying the same problem in multiple subject areas. Frequently, the diverse areas offer different emphasis. This results in synergy, the whole being more than the sum of its parts. The nuances of each discipline contribute to a higher-level understanding of the subject, which is not possible by examining each area separately.

In this paper, we study education and task mastery from the point of view of human education and machine performance. At first blush this may seem unintuitive. However, a mainframe computer with a collection of programs to run typically prioritizes them so as to run them in the most efficient manner. Remarkably, the rules governing the prioritizing of a collection of programs are in 1-1 correspondence with the rules governing student mastery of a topic. This affords a unique opportunity for multi-disciplinarity.

The benefits of this multi-disciplinarity should be obvious:

- Machines do not feel. The issues facing the machine in executing a program are performance measures accuracy, efficiency, and timeliness
- Contrastively, the issues facing a human in achieving mastery also involve motivation and feelings. Is the student motivated? Does the student have a sense of satisfaction in the mastery? Does a student have a sense of mastery?

Thus, by using an multi-disciplinary approach we benefit from an analysis both of performance, efficiency, motivation, and feeling.

3. Executive Function

We first review executive functions in people (Section 3.1 – 3,3) and then review it for machines (Section 3.4). The paper summarizes the comparisons and contrasts (Section 3.4).

3.1 Executive Function

Executive function refers to any activity of the mind that uses several mind components (Hendel, 2017). An alternative, sometimes useful, formulation is that multiple modalities of the mind are being used (Kendall, 2011, NCTM, 2000).

There are several classical examples illustrating executive function.

Example 1 – Calculus: Debra Hughes-Hallet reformed calculus education by requiring that calculus concepts be analyzed *verbally, computationally, formally, and graphically* (Hendel, 2015). This reform addressed the problem of students who, for example, excelled in formal calculation of extrema (maxima and minima) without understanding the graphical and computational nuances of the extrema.

Example 2 – The Trail Making Test (Bowie & Harvey, 2006, Corrigan & Hinkeldey, 1987, Gaudino, Geisler, & Squires, 1995, Reitan, 1958). This is a deceptively simple test which is routinely used neurologically to assess stroke damage and possibility of recovery. The test has 2 parts: Part A and Part B.

In Part A the testee is presented a paper with circles with the numbers 1 through 25. The examiner requests the testee to create with a pencil a trail starting at 1 and ending at 25.

In Part B, the testee is presented with a paper with circles with the numbers 1 through 12 and the letters A through K. The examiner requests the testee to create a trail starting with 1 going to A then going to 2 followed by B, etc.

While there is no right or wrong amount of time for completing the A and B parts, what is of interest to the examiner is the difference between the time needed to complete Test A and the time needed to complete Test B; test B always takes longer. The reason for this time difference is that Test B, although superficially a simple task, involves two components of the mind, one dealing with numbers and the other dealing with letters. This use of two components of the mind creates a need for the mind to use executive function and hence takes longer. A small difference in time diagnostically points to less expected damage from a stroke and a higher possibility of recovery from stroke.

3.2 Advantages of an Executive-Function Formulation: There are several advantages in re-formulating *pedagogically challenging* in terms of executive function.

- Objectivity and Clarity: The typical terms found in the hierarchies – *analysis, synthesis, evaluation* – lack specificity and possess ambiguity. Contrastively, executive function has a clear meaning: Either a given problem or example uses more than one mind function or does not.

- Support in major theories: Both the standards proposed by the National Council of Teachers of Mathematics (NCTM, 2000) and Common Core State Standards (Kendall, 2011) advocate use of multiple modalities which is a major contributing factor to executive function.

- Ease of Applicability: It is challenging for instructors to come up with *creative* problems or *evaluative* problems. Contrastively, any problem can easily be made to satisfy the requirements of use of executive function by having two subproblems (Hendel, 2013) or by reformulating the problem using multiple mind modalities such as verbal, graphical, computational, and symbolic. As noted above, despite the simplicity of Test B vs. Test A of the trail-making test, the addition of an additional brain area – recognition of numbers and letters – is sufficient to create a very powerful neurological diagnostic tool

- Psycho-neurology: Psycho-neurology has identified executive function as the driving factors in *higher level* mental tasks. That is, all known examples of tasks called *higher level* involve multiple mind tasks; contrastively; mental tasks considered low level, for example memorization, typically involve one mind task. By identifying the root psychological cause of *higher level,* we invest the theory with a certain amount of objectivity.

- Motivation and Satisfaction**:** Tasks involving executive function vest a feeling of mastery and satisfaction in those performing the task, create higher motivation because of the increased challenge of executive function problems, and because of the multiple brain areas involved are more readily transferred to new situations.

3.3 Clarification of the Type of Executive Function.

The term executive function can refer to:

1. Problems involving *multiple modalities* such as found in the rule of 4.
2. *Open ended executive function* for example, "You are on a vacation and discover that you did not take an important medication which must be taken daily. What do you do?" Open ended executive function requires using multiple mind areas without explicitly identifying which ones are used.
3. *Performance executive function* such as the trailmaking test which focuses on using explicitly identified multiple mind areas.
4. *Multistep problems* (Hendel, 2013) which although involving the same area of the brain might require solving a problem using two subproblems. A simple example from first grade would be the inquiry," 2 plus a number equals 7. How much is twice that number?"

Satisfactory results of pedagogic excellence can be obtained using methods #1, #3, and #4. While method #2 is powerful it is harder to implement. As pointed out in Section 3.3, it is easy to create a multi-step problem using method #4 by simply combining two problems. Contrastively, most instructors would be challenged to create daily open ended executive functions problems. In passing, when reviewing results from the literature on executive function and instruction it is critical to ascertain if open ended vs. performance executive function is used. Many negative results on the correlation of executive function with good pedagogy are only addressing open-ended executive function; these papers tend not to discuss performance executive function.

3.4 Machine Learning

For purposes of understanding machines learning, we can perceive the programmer as an instructor and the machine as the student. The issues of *pedagogy* facing the programmer-instructor are: *What method of instruction would lead to programs that succeed and that are efficient (in terms of time resources).* For this question there is a literature reviewing literally thousands of programs identifying both what works and what causes problems.

The literature is clear that modularized programs are easier to write, less likely to have errors, take less time to fix when errors are found, and are generally more efficient (Hardin, Jaume, Pessaux, & Veronique, 2021). But modularization is simply the reformulation of the programming task in terms of a *collection of subtasks each of which has its own life, its own inputs, its own outputs, and except for those inputs and outputs is independent of the other subtasks.* This formulation is cybernetic; it formulates efficiency in terms of system components and process flows independent of their content.

This definition of modularization is simultaneously exactly the definition of executive function, a task which intrinsically involves simultaneous use of multiple subtasks. Thus, executive function does the same thing for machines as it does for humans: it improves speed, accuracy, and reduces errors.

3.5 A Comparison: Machine vs Human Executive Function

As already mentioned in Section 2.4, the multi-disciplinary approach of simultaneously considering *learning* in machines and humans creates synergy from the multiple perspectives:

- <u>Machines:</u> The emphasis is on objective performance metrics: i) the speed of teaching/programming, ii) the success rate of execution, iii) ease of adjustments and fixing of errors, and iv) comprehensibility and readability of programs to new programmers (we may call this transferability).

- Humans: The emphasis is on the emotional aspects: i) do students *feel* they have mastered something applicable to a wide variety of situations, ii) do students feel challenged, iii) do students have more satisfaction in the learning process, iv) can they more easily transfer any learned skills to new but similar situations.

4. Goal Setting

This section reviews the definition of goal setting as well as presents the theory of best goal setting practices.

4.1 Definition

Goal setting refers to the creation of subtasks to accomplish a given goal. Suppose two managers or instructors or any other pair of people in a position of leadership have the same task to accomplish. If the task is complex, it is typically divided into steps or subtasks which are done by individuals or a team of individuals. Study after study has shown that different sets of subtasks, which reflect different goal-settings for the same terminal task, can have a significant difference in accomplishment of the task and the quality of performance.

4.2 Best Goal Setting

There are literally thousands of projects that are being accomplished each year thus giving researchers the necessary data to infer *best* goal-setting practices. There is also a huge literature on goal setting, especially in the business world, since proper goal setting has significant dollar-impact.

The most popular account of best goal setting uses the acronym S.M.A.R.T which states that best goal setting is accomplished if the subtasks are specific, measurable, attainable, realistic, and achievable timely (Hendel, 2017). However, a glimpse of the literature shows at least five other important attributes: clarity, challenge, commitment, feedback, and task complexity.

Hendel critiques the current lists of attributes because they possess duplication, use words in ways that are not standard, and are not always clear. Instead, four specific well-defined categories are presented which subsume the various lists. Goal setting that has the following four attributes:

- Clarity: One can recognize when the subtask and each of its steps is completed
- Lack of ambiguity: Each step in the subtask is clearly defined, that is, a staff member need not ask for any further clarification, and even a new staff member could follow the rules and accomplish the subtask
- Timeliness: The subtask can be completed in a reasonable amount of time
- Challenge: The siubtask is not easy. A considerable amount of attention and effort must be used by the person attempting it.,

such goal setting is best in the precise sense that it leads to the:

- Quickest accomplishments of the terminal goal,
- The highest quality of results, and
- Maximal satisfaction among the team members.

Examples clarifying these attributes are the following:

Example 1: Telling a student to produce a good essay or even a good paragraph lacks clarity.

The student has no way of recognizing whether the produced paragraph or essay is good. Additionally, there is ambiguity since the student does not know the steps to write the paragraph or essay.

In other words, writing a paragraph or essay could not be part of proper goal setting.

Example 2: The student is told to write a paragraph by i) first stating the topic sentence or main idea or the thought that the reader should take away with them after reading the paragraph, and then ii) giving three examples of the topic sentence.

Such instructions fulfill the four requirements of good goal setting: i) Clarity (the student can recognize when each subtask is complete), ii) lack of ambiguity (the student can accomplish the subtasks without asking further questions), iii) timeliness (the paragraph could be written in a reasonable amount of time) and iv) challenge (the task is not straightforward; the student must find three good examples).

However, the instructions are incomplete. For example, in writing an essay, you would not want every paragraph written that way. Several paragraph templates should be provided, and instructions would be given on where each template should be used.

The college textbook (Jones & Faulkner, 1977) provides an approach to essay writing that employs the best goal-setting practice consistent with the examples just given.

4.4 Human Goal Setting

The preceding sections adequately explain goal setting in a human setting. Whether a team or individual is performing the sub-tasks created by the good goal setting, good goal setting produces quickest performance, highest quality, lowest error rate, and maximal satisfaction.

More specifically, a person attempting to complete a clearly recognized subtask subgoal knows what they are aiming for and therefore is more highly motivated. Because the steps are unambiguous there is no frustration leading to abandonment during the subtask execution. Finally, the requirement of challenge assures that the person is fully engaged and devoting maximal attention. The consequence is quick accomplishment, good quality, a low error rate, and a sense of satisfaction.

4.5 Machine Goal Setting

Just as there is a huge literature on goal-setting in the business world, because goodness of goal setting has serious dollar impact, so too, there is a huge literature on good goal setting in the computer world, since most programs are complex, require careful subsequencing, and the resulting clarity of the program has significant dollar impact on the cost of the project.

The literature repeatedly shows that the best programs are those that are broken into subprograms with each of these subprograms requiring a clear input and having a well-defined output. This allows success because each module or subprogram stands by itself. The programmer can devote attention to taking the inputs, manipulating them, and producing the desired outputs. While writing a module the programmer need not think of the entire task and can focus on the task that they are doing.

We see here the goal-setting attributes of clarity (recognition of achievement of the terminal goal) and lack of ambiguity.

It is important that each module be challenging and not easy. As an extreme example good program writing would not consist of taking a 100-line program and assigning a module to each of the 100 lines thus creating 100 subtasks. There has to be a balance between the subprograms and the overall task. This balance is accomplished by the goal-setting attributes of timeliness and challenge.

Overall, good programming and good human subtasking share common attributes.

The next section summarizes.

Table 1: Comparison Of Good Goal Setting In Humans And Machines.

Goal setting attribute	Humans	Human benefit	Machine	Machine benefit
Clear (recognizable goals)	Subtasks	Motivation (aware of goal)	Modularization	Simplicity of design at each stage minimizing likelihood of error
Lack of ambiguity	Reproducable by even new staff	Lack of frustration and bottlenecks	Clear inputs and outputs	Efficiency: Each module writer works independently but modules can easily be integrated into whole
Timeliness	Accomplishable in a reasonable amount of time	Motivation; lack of putting things off	Good execution time of modules	Efficiency: Does not encourage lowering task priority because of time needs
Challenge	Not easy or straightforward	Requires full attention, engagement	Modules deal with high-level subtasks	Efficiency and readability; the subtasking does not become so overwhelming as to defeat its task

4.6 Human-Machine Comparison

Table 1 compares good goal setting in humans and machines with emphasis on emotional perceptive benefits for humans and efficiency-accuracy benefits for machines.

4.7 Applications to Best Syllabus Writing

Application of the principles of good goal setting to syllabus construction is fruitful and are as follows: *The syllabus submodules should reflect subtasks of a good goal setting of complex course goals.*

<u>Example:</u> Suppose we wanted to teach graphing of polynomials. This involves the following subtasks

- Identifying where the graph is increasing, decreasing, or level
- Identifying where the increase/decrease is leveling or itself increasing. For example, tracing the clock positions from 6 to 3 paint a picture of an increasing function (from the 6 o'clock position to the 3 o'clock position) whose increase is itself increasing).

It turns out that in calculus the level places of the graph (the tops of mountain-like regions or the bottom of valley- like regions) as well as the regions of increase and decrease can be inferred from the zeroes and signs of the various derivatives of the underlying function of the graph.

This suggests the following sequencing of topics in the syllabus consistent with good goal setting. The instructor should sequentially teach the following substeps:

- Obtaining the first derivative of a polynomial

- Obtaining the derivative of the derivative (the 2nd derivative) of a polynomial
- Identifying the regions/points where the first and second derivative are negative, zero, or positive.
- Using these regions to obtain a graph.

Polynomial graphing is simply one major component of any calculus course. The other major components of a calculus course can be analyzed analogously producing a *good* syllabus, that is, a syllabus reflecting good goal setting.

5. Attribution Theory

This section presents the basic tenets of attributions theory with traditional illustrative examples.

5.1 Basic Theory

Attribution theory has been re-discovered many times (Dweck, 1986, (Orbach, Singer, & Price, 1999, Wiener, 1985) and is an important predictor of student success. Attribution theory studies the student beliefs of the causes of student success. The theory posits that students are more likely to succeed when they believe that their success arises from controllable and internal activities. The following examples clarify this basic theory.

Example 1: *Effort and work* are activities that ii) the student controls and ii) are internal to each student (they do not depend on outside factors). The theory predicts that those students who believe their success is dependent on effort and work will on average do better than those students who do not.

Example 2: *Genius* while i) internal to the student, is ii) not something the student controls, Attribution theory predicts that students who believe that their success depends on whether they are geniuses tend to do poorer than students who believe that their success is dependent on their work and effort.

Example 3: *Being a teacher favorite* is i) external, and ii) something the student has only minimal control over. Attribution theory predicts that students who believe that their good grades are due to their being the teacher favorite tend to perform more poorly.

Attribution theory is applied in the classroom by encouraging instructors to create an atmosphere where students believe that their successes are due to internal controllable activities like work and effort.

5.2 Attribution Theory in Machines

Machines such as mainframes are frequently given multiple tasks. The machines have procedures to prioritize the jobs they do. Clearly:

i. Internal: A machine will prioritize jobs for which they have all data and subprograms. However, if the job execution is dependent on receiving external inputs, for example, data not currently available or modules not currently available, the machine will place those jobs at the end of the list of requested jobs.
ii. Controllable: Clearly, a machine will not prioritize a job for which it currently does not have the requisite modules. The machine will prioritize those jobs for which it can completely control execution.

5.3 Comparison of Humans and Machines

Attribution theory addresses:

- *Human feelings and beliefs:* Success of the student is dependent on their feeling, belief, and perception of success.

- *Machine efficiency and productivity:* In prioritizing jobs, the machine seeks to maximize its productivity and efficiency, the number of jobs it can execute.

- The success of machines in prioritizing jobs depends on whether the high priority jobs can be done quickly without waiting for outside support and provided the machine internally has all necessary data and modules.

We see here the synergy of multi--disciplinarity. Pedagogic success is heightened when greater productivity and efficiency can be achieved and when the learner (human or machine) sees, believes, and perceives that their internal controllable activities will lead to success. Contrastively, learning is slowed down when completion of learning depends on outside input over which they have no control.

6. Self Efficacy

This section presents the definition, history, importance, and primary drivers of self-efficacy.

6.1 Definition, History, and Importance

Self efficacy is a recent approach to motivation. It was introduced in the last few decades of the last century (Bandura, 1977, 1997, 2000, 2001). In contrast to the prevailing theories that human behavior is caused by unconscious forces within the individual, this new theory gave greater agency to the individual. According to this new theory the primary motivating factor of an individual is their self-efficacy, their belief that with their current skill set they can accomplish a particular task. Numerous studies in a variety of fields confirm that self-efficacy is the highest single predictor of success.

6.2 The Six Drivers of Self-efficacy

Self efficacy is driven or caused by six factors. They are summarized in Table 2, which lists them by order of importance.

6.3 Applications to human learning: The basic heuristic implied by the first two drivers in Table 2, performance and role models, is that for a learner to succeed they should successfully perform many *exercises* where and have many opportunities for *coaching*, mentoring, and having *requests for guidance* responded to.

A punchy example of how self-efficacy improves learning is the six-step cycle presented in a paper on using a graphical method, the tree-writing method, to improve essay writing (Nair et al, 2012). To understand the six-step cycle, the details of this method need not concern us here since we are more interested in its effects. The authors describe the recurring cycle presented in Figure 1 confirming that self-efficacy improves instruction and learning.

Notice how application of self-efficacy naturally involves the other pedagogical pillars discussed earlier in this paper.

- Executive Function: The method to master is typically multi-step and may involve several mind modalities (such as the tree-writing method involving a graphical technique to help in writing).
- Goal Setting: Self efficacy is primarily driven by past performances. As in the tree-writing method, the instructions start with teaching the method. To achieve learning the method must have clear subtasks, recognizable goals, be achievable timely, and be challenging.
- Attribution Theory: The students see the method as something they can control. Their practice is internal to themselves. Thus, the critical components of attribution theory are present.

Table 2: The Six Drivers Of Self-Efficacy

Driver of self-efficacy	Brief Description
Past performance	Numerous experiences of previous successful attempts to perform the activity. Past performance is superior if minimal guidance is needed, more effort is expended, and the tasks done were challenging.
Role models	Includes watching self-videos of past performance, peer performances, or performance of masters. Includes models of the entire act or specific parts of it. Role models are most efficacious when they have i) failed, ii) struggled to overcome failure, and iii) then overcome obstacles and succeed.
Persuasion	Includes verbal persuasion from oneself and from others. Includes both encouragement and specific feedback. Negative verbal reactions to failures (emotional outbursts) are detrimental to future success.
Physiological affects	Positive physiological effects correlate with future successes while negative physiological affects correlate negatively.
Emotional Affects	Positive emotional affects correlate with future successes while negative emotional affects correlate negatively. Emotional affects may include such things as anxiety and discomfort or even a feeling of lack of certainty.
Imaging	The learner imagines themselves either succeeding at the task, part of the task, or just imagines themselves confidence.

Teach method →
increased student practice →
decreased student anxiety in use of the method →
increased self-efficacy (confidence in using method) →
increased mastery →
increased enjoyment in practice →
increased student practice

Figure 1: Cycle Of Self-Efficacy Leading To Improved Learning

6.4 Application of Self efficacy to Machines Learning

As in our review of other human-machine learning, the emphasis in humans is on the emotional, *the student feels confident that with their current skill set they can perform a given task,* while contrastively, the emphasis in machines is on the cognitive: *the machine, say a mainframe, reviewing tasks it must prioritize and do, ascertains whether it has performed similar tasks in the past and whether it has available the various modules needed for its completion.*

In other words, both humans and machines seek to identify whether with their current resources they can complete the task. For the machine, the emphasis is on checking whether they have the resources; while for humans the emphasis is whether they feel and perceive they can accomplish the task.

For both humans and machines, the primary drivers of self-efficacy are important. Both humans and machines are encouraged by:

- Past performances of similar tasks
- Role models: in the case of machines the role models may be programmers or programs used by other machines

However verbal persuasion is unique to humans as is imaging and emotional affects. Physiological effects do affect machines like humans; a machine must monitor whether it is overheating, using too many electrical or networking resources etc.

7. Conclusion

This paper has examined good pedagogy from a cybernetic point of view and has used multi-disciplinarity to find commonality and increased crystallization of the concept of good pedagogy.

The cybernetic description of good pedagogy involves a description without regard to content but rather exclusively dependent on the internal system flow of the instruction process. More specifically:

- Executive function refers to multi-step processes as applied to any content; it speaks about multiple modalities applied to any content; this equally applies to machines and humans. Executive function increases mastery. Additionally, humans have the emotional effect of engagement, full attention, and a perception *this can be done* that arises from multi-step processes and multiple modalities

- Goal-setting for both machines and humans states that independent of content, success and mastery are enhanced and improved when sub-tasks have clear recognizable goals, with well-defined unambiguous steps to achieve them, with the capacity to achieve completion timely and yet be challenging (utilizing many resources). Moreover, humans have the emotional effect of increased motivation and satisfaction from seeing the outcomes of performance of sub-tasks as well as their timely completion.

- Attribution theory for both machines and humans emphasizes that independent of content, learning-performance is best when practices are internal, controlled by the learner, and require effort. Humans also experience increased motivation because they are the sole determiners of what is done.

- Self-efficacy although defined emotionally in terms of a feeling and perception that a task can be done, can also be formulated in content-independent terms as referring to adequacy of internal resources and past practice coupled with coaches, mentors, and models to fill in gaps.

We believe this review should greatly clarify the requirements of good pedagogy without obscuring it with technical terms such as *analysis, creativity* and without obscuring it with emotionally charged words and phrases like *higher cognitive*. We encourage instructors, independent of discipline and level, to actively apply the methods presented.

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