Enhancing Writing through Strengthened Executive Function

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ABSTRACT

We explore aspects of essay writing requiring high-level organizational capacity and executive function. The literature supports the approach that specific and focused writing-skill mastery leads to reduced anxiety and increased self-efficacy which correlates with improved writing skills. Although essay writing is a complex multi-dimensional task, two particular strategies, *tree-diagram* and *reference* methods, specifically address the organizational skills characteristic of executive function. The tree and reference methods presented in this paper address the flow of information, not content, and consequently, the methods presented in this paper apply to mathematics and English as well as to K-12 and college level.

Keywords: essay writing, composition, skill mastery, reduced anxiety, self-efficacy, improvement, tree diagram, reference, executive function, cybernetic, organization, planning

1. GOALS, OVERVIEW AND BACKGROUND

The complex multi-dimensional nature of essay writing is well known. Writing is cognitively demanding, complex and multifaceted. The important component of essay writing is the *integration* of basic writing skills into a whole, not the component skills themselves. The key point to emphasize is that writing is *multi-dimensional*.[8].

Another example of the complexity of writing is seen in large scale admission tests which prefer direct writing assessment in the form of holistically scored timed writing samples to multiple choice tests which continue to be criticized for their lack of construct representation as well as for their potential to differentially impact racial and ethnic groups [22].

1.1 Focus on Organizational Executive-Function Skills

This paper focuses on the more complex skills needed for writing with particular emphasis on tasks involving higher order cognitive skills such as argumentation, skillful integration of ideas from source texts and increased construct representation.

More specifically, this paper focuses on skills requiring *executive function.* Executive function is roughly defined as the skill to integrate several other skills into a new whole. "People use executive function to perform activities such as planning, organizing, strategizing, paying attention to and remembering details, and managing time and space. People with weak executive function, have difficulty in writing, they struggle to communicate details in an organized sequential manner. Lack of executive function is a learning disability and can be found in children of all ages" [26].

This paper focuses on organizational aspects of writing. "Good writers appear to have more flexible, high-level plans and more self-conscious control of their planning than poor writers" [19,20]. The emphasis on high-level writing planning is characteristic of executive function. Executive function is very clearly operationally defined and can be improved through simple strategies. Additionally, executive function correlates with distinct brain structures.

Accordingly, section 2 lightly reviews several educational hierarchies. Then section 3 reviews some literature on the deceptively simple trail-making test that nevertheless intrinsically requires executive function. These sections show a convergence of theories pointing to the need for improved executive function as a means to improved writing.

1.2 Content independent formulation

Sections 4 and 5 present writing methods that are independent of content; rather, they focus on the pure flow of information. The methods can be applied to both mathematical and English writing and can be applied to any age level. The impetus for this paper came from the author's attempts to improve written answer mathematical problems in a college course.

1.3 Writing-teaching strategies

Section 4 reviews several methods of writing improvement. These include POW, TREE, and COPS. A method like COPS – *Capitalize, Organize, Punctuate Sense* – however useful, is not relevant to this paper since the skills required for COPS do not primarily involve executive function. Rather, this paper presents two methods: the *tree-diagram* method and the *reference* method which are useful in higher mathematics.

2. COGNITIVE CHALLENGE

This section reviews several pedagogical hierarchies each of which attempt to define cognitive challenge.

2.1 The Bloom-Anderson Hierarchy [1,2]

Benjamin Bloom headed a group of psychologists who, in the early fifties, proposed a 6-level taxonomy of learning skills This taxonomy has been widely used. It was improved and expanded in the nineties by Lorin Anderson.

The original six Bloom levels are *knowledge, comprehension, application, analysis, synthesis, evaluation.* The new Anderson levels are *remembering, understanding, applying, analyzing, evaluating, creating.*

2.2 Gagne's Hierarchical Learning [13]
Robert Gagne developed Hierarchical Learning. This theory identifies prerequisites that should be completed before the learner advances to a higher level of learning. He believed that all learners have to pass through these levels and no learner can skip a level. Gagne postulated eight distinct categories where learning can take place. Gagne observes a number of useful generalizations that can be made about all categories of learning. More specifically, Gagne introduced a sequence of nine levels that must be included in any effective learning: *attention, objectives, short-term memory, information presentation, performance, guidance feedback, assessment,* and *transfer.*

2.3 Piaget's Hierarchy [17]
Jean Piaget specifically studied development in children. He identified four stages of cognitive development: *sensory motor, pre-operational, concrete operational,* and *formal*.

The formal stage corresponds to a higher cognitive level where previously learned material becomes examples illustrative of formal abstract principles.

2.4 Van Hiele [32, 33]
Van Hiele specifically developed his theories of pedagogic development for geometry. Van Hiele posited five levels of development: *Visualization, analysis, informal deduction, formal deduction,* and *rigor*. The five Van-Hiele stages of development have several common distinct attributes: *fixed sequence, adjacency, distinction, separation and attainment*.

2.5 Commonality
Many of these theories are interchangeable descriptions of the same process using different constructs. For example, although learning geometry is often associated with the van Hiele approach, preliminary studies suggest that Gagne's Hierarchal Principles are as effective as van Hieles' approach in learning geometry [33].

Each of the above theories has cognitive levels that require executive function, the integration of two or more distinct skills. The following hierarchy items illustrate these advance levels: Bloom-Anderson's *analyzing, evaluating* and *creating*, Gagne's *transfer*, Van-Hiele's *formal deduction* and *rigor*, and Piaget's *formal stage*. Thus there is a convergence and consensus of theories that the higher levels of pedagogy involve strengthening of organizational skills and executive function.

3. EXECUTIVE FUNCTION

In this paper we focus on executive function itself, rather than the specific categories in traditional learning hierarchies that require executive function. The advantages of studying executive function are that it is simply operationally defined as the capacity to integrate two or more distinct skills. Additionally, executive function can be strengthened by simple activities. We review two such activity strategies in this section.

3.1 The Trail making Test [6,10,14,30]
The trailmaking test is a simple two-part test with the following parts.

- Part A of the test, requires a person to connect 25 circles with randomly placed numbers between 1 and 25 in order. A correct response would be 1,2,3,4,….
- Part B of the test requires connecting 25 circles with randomly placed numbers and letters. A correct response would be A,1,B,2,C,3,….

As can be seen, Part A is a single-step task (enumerate 1,2,3…) while Part B is a two-step task, involving enumeration of both letters and numbers.

Superficially, Part B, does not appear that much different than Part A. Yet the "scores" on the two parts – the time required to complete the parts – are statistically significantly different. In fact, and surprisingly, this trailmaking test is routinely used in clinical settings to test for brain damage and the possibility of recovery after stroke.

Clinicians theorize that the Part B test requires executive functions and consequently tests higher-level brain activity. The trail-making test has traditional attributes of good tests such as *validity, reliability and consistency.*

3.2 The Two-step K-12 Multiplication Example [21]
The following simple set of examples clearly illustrates the contrast between executive function and memorization of raw facts at the K-12 level:

> Consider a 5-th grade class with the curriculum topic, *multiplication table*. We assume the students have not yet learned the division table. The following three test items each assess the same learning objective, learning of the multiplication table; however, they dramatically differ in the skills they measure.
>
> - Test item #1a: Give the product of 7 x 8.
> - Test item #1b: Samantha wishes to purchase a different colored piece of liquorice for each day of the week. Each piece of liquorice costs 8 cents. How much will the purchase for the week cost?
> - Test item #2: (a) A certain number when multiplied by 8 equals 56. (b) Give the product of that number with itself.

Test item #1a is a *raw fact* from the multiplication table. Test item #1b tests the same raw fact underlying test item #1a by requiring the student to do real-world modeling. Contrastively, test item #2 has the following executive function feature, endowing it with superiority over test items #1a and #1b: Test item #2, requires *two* applications of the multiplication table; these two applications are marked (a) and (b). Since test item #2 requires two applications of a previously learned skill it requires executive function (similar to the trailmaking test). Such problems are called TSPs, *two step problems*; they are an operationally simple method to introduce a superior level of challenge into teaching at any level. An alternative formulation of the superiority of test item 2, is that it requires use of the missing factor strategy.

4. WRITING STRATEGIES

A variety of papers [3,24,31] explore different approaches to improving writing. A pooling of all stages from these papers results in the following all-inclusive sequential hierarchy:

- Knowledge of writing strategies
- Mastery experience of these strategies

- Removal of writing anxiety
- Improved self-efficacy
- Increased writing effort
- Improved writing

In other words these papers show e.g. that

- less successful writers typically have fewer strategies.
- teaching specific strategies dramatically reduces anxiety and excites students who now believe there is a concrete and specific method to improve.
- removal of anxiety improves self-efficacy, or writing self-esteem, the belief of the writer that they can write (independent of their actual ability).
- self-efficacy improves writing through the mediating variable of more effort; the higher the self-efficacy the higher the effort put in.

4.1 Writing Strategies

[5] presents several evidenced based writing strategies as well a six step method of implementing them. The writing strategies presented include

- COPS – *Capitalize, Organize, Punctuate, Sense*
- TREE – *topic sentence, reasons, explanations, ending*
- POWER – *pick my idea, pay attention to the prompt, organize, write and say more*

Also see [12,15,29].

[5] recommends imparting these strategies through SRSD, self-regulated strategy development, which has been shown to have positive effects in writing for adolescent students with and without disabilities as well as offer adult GED students with and without disabilities a method for meeting the GED writing requirements [7,16,28].

SRSD uses six evidence-base strategies for learning acquisition. They are presented in Table 1 with the Hartley –Lovell-Ohlsohn stages of good tutorial design [18,27]. Table 1 emphasizes that different researchers have identified the same "good" learning techniques albeit with different names.

Hartley Lovell Ohlsohn	SRSD
Student Cognitive model	*Student* Background knowledge
Software representation of the *model*	Discuss strategies to be learned
	Model the strategy
	Memorize the strategy *model*
Teach based on *strategy*	Support *strategy* use through guided practice corrective feedback, fading prompts
	Independent use and assessment of *strategy* mastery

Table 1. Comparison of Hartley –Lovell – Ohlsohn and SRSD

4.2 Tree Diagram Strategy [9,25]

The *Tree Diagram* strategy advocates utilizing a diagram which has branch like subdivisions. The basic idea is to use the visual diagram to indicate the relationships between the major paragraphs of an essay. Consequently, the *Tree Diagram* assists the student in essay organization. Examples of a minor variation of this method will be provided in sections 5,6,7 which apply these methods to English, K-12 mathematics and upper level mathematics. The use of *Tree Diagrams* gives students a concrete tool with which they can achieve mastery, leading to decreased anxiety, increased self-efficacy and consequent improved writing.

4.3-Reference Strategy

I have not found an explicit formulation of this strategy in the literature, though the idea is obvious. The idea is that essay argumentation frequently refers citations from other components of the essay. A *reference* strategy is simply a mechanism to unambiguously refer to other parts of the essay. In mathematical writing, internal reference is accomplished through numbered equations. In English writing, internal reference is accomplished through skillful use of keywords.

5. COLLEGE LEVEL MATHEMATICS

This section applies the tree-diagram/reference methods on a typical insurance premium problem that occurs in an upper level actuarial mathematics course. Students take these courses to learn content to prepare them for the Society of Actuary and Casualty Actuary Society actuarial examinations. Passing these actuarial examinations is the primary prerequisite for a student to be recognized as having sufficient actuarial competence to obtain entry-level jobs. A typical textbook is [11] which was used in the course.

5.1 Writing Anxiety

A primary motivation for developing the methods of this paper was reducing writing anxiety, particularly in weaker students. The literature describes three types of writing anxieties [4].

- Non-starters: These are students who might stare at questions blankly not knowing "where to begin." Nevertheless, if prompted appropriately during office visits by the instructor with "How do you begin?" these students would know how to begin.

- Non-completers: This refers to students who know how to start a problem, but their solution papers stop abruptly. Nevertheless, during office visits with the instructor, if prompted appropriately, the students could continue the work already on the paper. It should be added that the *appearance* of student-solution papers is also consistent with anxiety. Work is not presented in a linear manner. Computations are sometimes done "on the side" and not directly contiguous to the equation begin developed.

- Non-exhibitors: These are students who both begin and complete their work but are very skimpy. Nevertheless, during office visits with the instructor, these students could complete the work they had not exhibited, when prompted appropriately.

After the author introduced the two methods presented in this paper – the *tree diagram* and *reference* methods – there was anecdotal observational evidence of reduced anxiety among students. More specifically, in homework and test solutions, the author could see a reduction in the number of incidents of non-

starting, non-completion, and non-exhibition. Students who previously could not begin problems now had the tools to begin and office visits with the question "where do I begin" diminished. Further, more precise, studies in this area would be welcome.

5.2 Illustrative Use of Tree Diagrams with References

Figure 1 shows the tree development of the problem listed below. The symbols *a*, *A*, and *E* are actuarial symbols representing annuities while surviving, insurances upon death and deferment factors respectively. They can be looked up in tables. Figure 1 is a *linear* development of the solution while Figure 2 is the *tree* representation of this solution.

> Problem: Using the equivalence principle, a principle of break-even between required payments and cash inflow, compute the annual premium payments for a 45-year old that suffice to pay for an insurance of 50000 upon death and starting at 65, annual retirement payments of 36000 while alive.

1. Break Even principle: INFLOW = OUTFLOW
2. (1) INFLOW: Annual premium payments until 65
3. (1) OUTFLOW: Death benefit, retirement annuity
4. (3) Death benefit: Benefit of 50,000 upon death
5. (3) Retirement annuity: 36000/year while alive
6. Algebraic formulation of (2): $P\ a_{45:20}$
7. Algebraic formulation of (4): $50{,}000\ {}_{20|}A_{45}$
8. Algebraic formulation of (5): $36{,}000\ {}_{20|}a_{45}$
9. Algebraic formulation of (6): $P\ a_{45} - P\ {}_{20}E_{45}\ a_{65}$
10. Algebraic formulation of (7): $50000\ {}_{20}E_{45}\ A_{65}$
11. Algebraic formulation of (8): $36{,}000\ {}_{20}E_{45}\ a_{65}$
12. (3) redone with (4,5) redone with (7,10 & 8,11): OUTFLOW=$50000\ {}_{20}E_{45}\ A_{65}+36{,}000\ {}_{20}E_{45}\ a_{65}$
13. (2) redone with (6,9): INFLOW= $P\ a_{45} - P\ {}_{20}E_{45}\ a_{65}$
14. (1) redone with (2,3,12,13) $P\ a_{45:20} = 50000\ {}_{20}E_{45}\ A_{65}+36{,}000\ {}_{20}E_{45}\ a_{65}$
15. (14) redone with lookup of numbers in table (Technical details omitted)
16. (15): solve for unknown P

Figure 1: Tree development of the solution to the problem enunciated at the beginning of the section. Figure 2 shows the tree structure.

(1) INFLOW=OUTFLOW
(2) INFLOW: P, 20 years (3) (3)
(4) (5)
(6) $P\ a_{45:20}$ (7) (8)
(9) $P\ a_{45} - P_{20}\ E_{45}\ a_{65}$ (10) (11)
(12)
(13) INFLOW= $P\ a_{45} - P_{20}\ E_{45}\ a_{65}$
(14) INFLOW=OUTFLOW
(15) Look up actuarial symbols; plug #
(16) Solve equation for P

Figure 2: Tree structure of the solution presented in Figure 1.

Let us sketch how this tree diagram could remove anxiety. Students are told to *begin* problems with a broad statement of the equivalence principle in English. The equivalence principle asserts that the premium inflow to the insurance company when adjusted for survival and interest should equal the claim outflow for death and retirement adjusted for survival and interest. This is node (1) in Figure 2 and is labeled INFLOW=OUTFLOW.

We now have two concepts that must be developed: INFLOW and OUTFLOW. The left branch in Figure 2 develops INFLOW while the right branch of the tree in Figure 2 develops OUTFLOW. Let us explore the left branch.

In node (2) we develop the idea that INFLOW corresponds to premium payments for 20 years by a person aged 45. At this point we are still speaking in English. In node (6) we give the actuarial symbol for 20 years of premium payment by a person aged 45, $Pa_{45:20}$. In node (10) we further develop this premium payment into an equivalent symbolic formulation that however uses symbols that can be looked up in an actuarial table (The symbol in node (6) cannot be looked up). Finally in node (13) we summarize the path (2)-(6)-(10)-(13): INFLOW= $Pa_{45} - P\ {}_{20}E_{45}\ a_{65}$

The details of development of the right branch are omitted. The main thrust of using the tree diagram method is that each branch can be developed separately; the two developed branches can then be woven into an entire problem solution presented in a linear fashion as shown in Figure 1. We see here the requisite twoness corresponding to executive function. The problem has many parts and the challenge to the student is *organizational*, placing the parts together; each part however is simple.

We can also see how this tree-diagram method can alleviate student anxiety. Consider a non-starter who does not know where to begin: We simply tell the student to always begin the problem with a broad English statement that payment inflows and outflows are equal. We also tell the student the key idea of development: "Take the terms you just mentioned: (INFLOW and OUTFLOW), and list them next in the list (or tree)." This key idea is applied over and over. At each step the student is doing something very minor and therefore can achieve this without anxiety. As noted in [25] concerning English writing: "The tree diagram gives the student a tool for mastery and control of the writing process; this mastery increases perceived self-efficacy, leading to more motivation and better writing output."

Note that we have not actually written the "essay." We have rather listed the topic sentences of the essay. Each of the nodes can be expanded in a paragraph. For example node (2) can be expanded into a paragraph as follows:

> In paragraph (1) we refer to the stream of payment inflows. The only source of payment inflow is the premiums which the purchaser pays. These premiums are paid annually at the beginning of each year until the 45-year old reaches 65 and provided the person paying is still alive. If the person dies prematurely (prior to age 65) no further premiums are paid.

This use of small topic sentences facilitates removal of the non-completeness and non-exhibitionist types of anxiety.

5.3 Removal of Student Anxiety

The tree-diagram presented in Figure 1 develops the solution at a leisurely rate. As long as students are taught to start from basic principles (INFLOW=OUTFLOW) and to successively develop the terms in each current statement, the solution flows without inhibitions. This method was useful in removing anxiety from several students who were non-starters.

A final point to be made is that the use of numbered paragraphs enables the non-exhibitors to keep track in an orderly and meaningful manner of "what still has to be done." By referring to previously numbered paragraphs, students are able to show details without the typical "side calculations" which make papers unreadable.

5.4 Assessment

An important issue in any proposed learning strategy is assessment: How do you assess success of your proposed method? [5] presents four criteria of assessment for writing strategies: a) number of essay parts, b) number of transition words, c) number of descriptive words and d) essay length.

At this stage of research my assessments are observational and anecdotal. However, my observations are sufficient to encourage more rigorous assessments.

I taught the writing procedures presented in this paper by requiring, in my Actuarial Mathematics course, that certain written-answer homeworks are handed in using the format in Figure 1. After using this procedure, I have observed, particularly in weaker students, that

- The number of essay parts ("paragraphs") has increased,
- White space to distinguish separate paragraphs has increased (thereby indicating that students are thinking componentially), and
- The number of references has increased (thereby indicating increased organization).

Grades have also improved but that is possibly attributed to the clearer showing of work in component parts thus allowing partial credit.

6. K-12

The two tools introduced in this paper, tree-diagrams and referencing, are content independent. In other words they are cybernetic in flavor since they address the flow of information not its content.

My primary experience is teaching at the college level. Thus the examples in this and the next section are theoretical, conjectural and exploratory. I bring them to suggest how these methods can be used at different educational levels. Perhaps other researchers will create studies based on these methods.

The following problem, dealing with K-12 content can be treated the same way as the premium example of Section 5.

> Johnny wishes to purchase some snacks for his friends. He wants two 6-packs of soda, four bags of candy and three boxes of cookies. He knows that at his local grocery store, candy sells for $1.25 a bag, cookies for $2.50 a box and 6-packs of soda for $3.50. How much money will he need to purchase the snacks?

For reasons of space I omit the tree diagram. The basic idea is to compute a price by using the fundamental equation:

Price of several units = Price per unit x number of units.

The "written answer" would then apply this principle separately to candy, sodas and cookies and then unify the disparate equations (i.e. paragraphs) in a summary equation (paragraph).

A possible objection is that some "5th graders could write down the summary equation without breaking it up into component parts. Breaking it up may in fact confuse something simple."

My response to this is twofold:

- The methods presented in this paper were developed to address executive function. One can diagnose executive function deficiency by noting students who are successful at single formula plug-in problems but are unsuccessful with multiple problems. I conjecture that practice with the methods used in this paper would ameliorate the deficiency and welcome further studies on the matter.
- I have, for illustrative purposes, deliberately selected a simple multi-step problem. There are only 3 parts and each part applies the *same* equation. More complicated problems could be created with multiple parts using *different* methods.

7. ENGLISH [9,25]

The original *Tree-diagram* method was developed for English and hence will not be repeated here. The basic idea is to create a graph of paragraphs and link the corresponding thoughts with lines. "This graphical aid excites students, decreases anxiety, increases practice and mastery and hence improves writing" [25]. [9.25] provide actual examples.

8. CONCLUSIONS AND FURTHER RESEARCH

This paper has introduced two writing-enhancement strategies: *Tree-diagram* methods and *reference* methods. Both these methods deal with flow of information and are content independent. There is already some literature indicating that these methods reduce three types of writing anxieties and enhance writing organization. There is also literature proposing four specific numerical assessment measures. Further evaluation is needed using double-bind studies showing a statistically significant before-after improvement. This evaluation should preferably be done at both the K-12 and college level. Suggestions for further studies are listed throughout this paper.

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