Several Interdisciplinary Applications to UDL

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ABSTRACT

Universal Design in Learning (UDL) is a relatively new pedagogic approach which is especially successful in facilitating learning by students with learning disabilities. This paper explores application of several other disciplines to UDL, examining the potential to increase usage and success of UDL achievements. The paper is exploratory, reflective, and theoretical rather than explicitly empirical. The paper specifically examines four other disciplines: i) Since UDL is rooted in United States congressional laws, the paper shows UDL could benefit from UDL-like learning experiments in other countries. ii) The paper shows commonalities between UDL and the traditional pedagogic hierarchies with emphasis on transferring and applying the rich literature on executive function and goal setting in the business world to education. iii) The Van-Hiele theory is brought to suggest that personality types and some mental abilities may not be permanent, but changeable. iv) The paper advocates application of the Holland vocational psychology theory which emphasizes (vocational) preferences vs. permanent personality characteristics and abilities.

Keywords: UDL, universal design in learning, pedagogic hierarchies, personality types, Holland types, executive function, goal setting, holistic approach, analytic approach, vocational

1. GOALS

The purpose of this paper is to present potential applications of other disciplines to Universal Design in Learning (UDL). Awareness of the commonalities of these other disciplines and UDL, should lead to the strengthening of UDL by using an interdisciplinary approach.

The paper is exploratory and theoretical; it is not empirical. Ideally, specific interdisciplinary contributions would first be identified with a consequent comparison of treatment of UDL settings with and without the interdisciplinary contribution. Traditional statistical tests would then be used to prove or disprove the efficacy of the suggested interdisciplinary approach. It is however hoped, that this theoretical exploratory paper will spark interest in researchers who will follow up with such studies.

More specifically, this paper will explore interdisciplinary overlap between UDL and i) other (non U.S.) legal systems, (ii) the pedagogic hierarchies, iii) the Van-Hiele and iv) the Holland vocational theories.

2. UDL

2.1. UDL. At a high level, UDL encourages multiplicity of approach to i) motivation, ii) instruction, and iii) assessment. Figure 1 illustrates these three targets of multiple approaches.

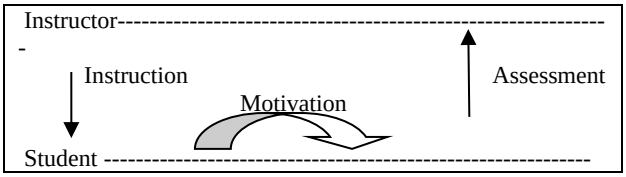

Figure 1: The traditional three areas of UDL emphasis.

Instruction is a dialogue from the instructor to the student; *assessment* is a dialogue from the student to the instructor; *motivation* is a dialogue from the student to himself. An example of multiple approaches to instruction would include visual, auditory, kinetic (projects), and each of these would also have multiple sub-approaches; for example, multiple visual approaches include written text, powerpoints, videos, use of colors and sound effects for purposes of emphasis etc. The graphics UDL organizer [7] provides a compact summary. The multiple approaches include use of technology to assist in transmissions.

The central idea in UDL is that students who are thought to learn poorly or incapable of learning might satisfactory learn using different approaches. An alternate formulation is that proper application of UDL should erase access barriers to education and facilitate the universality of education to all learners.

2.2. The Literature. The literature on UDL is quite extensive. Even restricting the search to publications in the past few years shows books: i) on the general theory and idea of UDL [30,39], ii) with specific hands-on operational techniques [14,27,33,36], and iii) addressing specific curricula, student populations, and subjects [21,25,26]

For purposes of writing this paper, the paper, "UDL: A Blueprint for Success" [38] was selected since it is recent, short, detailed, comprehensive, and covers several UDL areas and issues.

3: UDL AND LEGAL INTERDISCIPLINARITY

3.1 American Public Laws. Although UDL exists as a stand-alone pedagogic approach, it is also required by four laws of Congress, The Assistive Technology Act of 1998 [4], The No Child Left Behind Act (NCLB) of 2001 [29]. The Individuals with Disabilities Education Act (IDEA) of 2004 [20], and the Higher Education Opportunity Act of 2008 (HEOA) [17].

These laws steer UDL direction by determining funding [35], sometimes based on specific U.S. based curriculums [38] such as those meeting the Common Core State Standards guidelines [8]. A tension is thereby created since the universal goals of UDL may be restricted by the specific U.S. curriculum requirements.

An example of these potential difficulties is found in Dylan, the hypothetical student discussed in [38]. Dylan is described as follows:

> He receives instruction connected to his school's curriculum for all students, which is based on the Common Core State Standards. But whereas the Common Core recommends that 3rd graders should be able to represent and solve multistep word problems involving multiplication and division, Dylan is still working on one-step problems—a goal that appears in his IEP. The Common Core standards for speaking and listening require that students "engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 3 topics and texts." Dylan's challenges related to paying attention and maintaining friendships affect his proficiency on this standard. His IEP contains goals for paying attention when others are speaking and developing friendships with peers. Because there are other students in his class who also struggle with attention, his teachers often focus on these goals when designing group work.

In other words, Dylan has problems because of the specific curriculum guidelines of the Common Core State Standards. Section 3.2 presents alternative approaches that could lead to greater student success. Section 6 presents more fully methods for generalizing the approach in Section 3.2.

3.2 An Alternative Legal Approach: The AMIT State Technological High School in Jerusalem [1], one of the many innovative projects of the AMIT religious educational (K-12) network in Israel, an educational network committed to integrating the most modern educational advances in K-12 education [2], provides an interesting alternative legal approach to UDL.

In UDL terminology, the approach of the State Technological School could be formulated as follows:

> Our students, because of their low socio-economic background, undiagnosed learning disabilities, and continued failure in traditional education-support systems are disabled *with respect to traditional curriculum.* However, the terminal functional goal of education is not proficiency in reading, writing, mathematics, and computers. Rather the terminal functional goal of education is "to provide each student with a profession and the skills necessary to turn their lives around," enabling students to achieve self-sufficiency in the countries workforce.

Consequently, AMIT experimented with changing the curriculum, not the student. The State Technological school curriculum focuses primarily on auto-mechanics, electronics, graphic design, and hair styling. Importantly, the state recognizes these students as having achieved a K-12 education. The following excerpt briefly describes the amazing success this approach has had with poor, vulnerable, troubled students.

> Many of the 160 students at the AMIT State Technical High School have not met the academic requirements of traditional schools; they are among the capital's poorest and most vulnerable children. They often arrive at the school with previously undiagnosed learning disabilities or behavioral problems; many are known to the authorities.
>
> "We aim to provide each student with a profession and the skills necessary to turn their lives around," says assistant principal Bat Sheva Segavi. "Our students have no other options left. Succeeding here is vital for them to live good productive lives." The school provides each student with regular meetings with a social worker and psychologist. Personal development is a focus of the educational program, with an emphasis on fostering mutual trust between the students and teachers. Mutual responsibility is also stressed, 96% of the male graduates serve in the IDF (Israeli Defense Forces) (55% in combat units), and 93% of the females serve in either the IDF or national service.
>
> The approach has been highly successful. The school's flagship is the "Autotech Tools for Success" program, a state-of the-art program that places its students at the forefront of advanced automotive diagnostic and technological studies. The school has recently partnered with the IDF's prestigious Technological and Logistics Corps responsible for advanced weaponry development [1].

Several American local education agencies are also successfully experimenting with a vocational approach to education. Maryland has a strong Career and Technology educations (CTE) programs with programs falling under 10 career clusters [10].

The examples presented in this section give the flavor of the interdisciplinary collaboration which this paper seeks to explore.

4. THE PEDAGOGIC HIERARCHIES

Section 6 fully develops the idea of a vocational basis for curriculum guidelines. To fully appreciate the vocational approach presented in Section 6, this Section 4, reviews current approaches to good pedagogy or pedagogic challenge. This is followed in Section 5, by an analysis, from the point of view of good pedagogy, of the curricula issues causing Dylan difficulty. Section 5 shows how certain curricula components which are classified as good pedagogy or pedagogically challenging were therefore included in Dylan's curriculum. With this background, alternative formulations of criteria for curricula development can be presented which incorporate both concepts of good pedagogy as well as concepts of vocational challenge; the resulting curriculum should facilitate the same type of successes for Dylan as the programs of AMIT and Maryland, mentioned in Section 3.2, provide for their students.

This section reviews three sources of definition of pedagogic challenge: A) the pedagogic hierarchies of the 20th century, B) Hughes-Hallett's calculus reform, and C) Hendel's recent unifying treatment of the hierarchies with an emphasis on executive function and goal setting.

4.1 The Pedagogic Hierarchies: Abraham Bloom [5] created the first pedagogic hierarchy which was later modified by Anderson [3]. The idea of a hierarchy is that early levels in the hierarchy indicate cognitively simple tasks while later levels in the

hierarchy indicate cognitively challenging tasks. Since Bloom, many alternate hierarchies have been presented including those of Gagne [12], Marzano [24], and Van-Hiele [44]. Figure 2 selects for illustration the revised Bloom-Anderson hierarchy since it is the oldest and most widely used. The Bloom-Anderson hierarchy is contrasted in Figure 2 with the Marzano hierarchy. These hierarchies were selected because they have influenced i) the various guidelines to curriculum instruction such as the Common Core Standards [8], as well as ii) approaches to problem solving such as the Polya problem solving method [34].

Figure 2a: Bloom-Anderson	Figure 2b: Marzano
Memorize– list, define, know, tell *Identify* – cite, describe, outline, ask *Apply* – organize, use, illustrate act *Analyze* – examine, dissect, investigate *Synthesize*– design, produce, imagine, invent *Evaluate* – compare, critique, recommend	*Recognize-recall* *Represent-symbolize* *Analyze* *Problem – Decision Making*

Figure 2: Stages of the Bloom-Anderson and Marzano hierarchies.

4.2 Hughes-Hallett. Section 4.3 below presents Hendel's proposed unification of the hierarchies. To motivate Hendel's approach, this section presents the Hughes-Hallet approach to calculus reform. Unlike Bloom, Anderson, and Marzano, Deborah Hughes-Hallett does not specialize in psychology or instructional design. Rather, Hughes-Hallett introduced calculus reform [19]. Her basic idea is that calculus should be taught with what she called the *rule of four*, that is, every idea should be presented using four modalities: verbal, graphical, formal-algebraic, and computational.

Figure 3 summarizes key points of this approach using extrema as an illustrative example. Every calculus student knows that extrema can be identified using the 1st and 2nd derivative tests, algebraic manipulations of the underlying functions. Hughes-Hallett argues that students should also be able to identify: i) extrema using graphs (e.g. the simple idea that the vertex of a V-like graph is the minima of that graph and its underlying function), ii) extrema using function tables, and iii) a request for extrema in a verbal problem.

III.C Executive Function: Yazdani [45] shows that the Gagne and Van-Hiele theories, two very differently formulated pedagogies, could nevertheless, lead to equal classroom improvements. Hendel [15] continued this search for an underlying unity in the pedagogic theories. He suggests that all theories of educational excellence rest on four pillars: i) executive function, ii) goal-setting, iii) attribution theory, and iv) self-efficacy. Pillars i) and ii) are examined next.

i) Executive function refers to the brain function that allows integration of several brain areas [31,41]. Although many features are connected with executive function, this paper finds it most useful to concentrate on the aspect of executive function that refers to the simultaneity of integration of several brain areas.

RULE OF FOUR

Formal -Algebraic – *locate extrema using the 1st and 2nd derivative tests*

Graphical – *locate extrema using graphs and visual identification of points*

Verbal – *identify requests for extrema in verbal problems*

Computational – *identify extrema through a function table*

Figure 3: Debra Hughes-Hallett's Rule of Four.

The executive function concept unifies the pedagogic approach articulated in: i) Hughes-Hallett's rule of four, ii) the *analysis-synthesis* levels of Bloom-Anderson, and iii) the *analyze and problem – decision making stages* of Marzano. Any cognitive activity that uses multiple brain areas, whether assessing the multiple parts of a procedure (Bloom's *analysis* level), creating an innovative design integrating a specific learned skill with another area (Bloom's *synthesis* level), or applying a learned skill to a new situation (Marzano's *problem and decision-making* level), is employing executive function. Hendel therefore argues that the driver of higher cognitive thinking is executive function.

The trail-making test highlights the power of even using just two very simple areas of the brain [6,9,13,37]. Figures 4a and 4b present a simplified Trail-Making test.

Figure 4a – The "A" Test	Figure 4b – The "B" Test
1 3 5 4 2	1 3 2 B A

Figure 4: Miniature Trail-Making test.

To administer the Trail-Making test, two cards are presented to the examinee, one for the "A" test and one for the "B" test. The A test typically has 25 numbers, 1 through 25, scattered randomly; Figure 4a has 1 through 5. The B test typically has 25 numbers and letters; Figure 4b has 5. To take Test A, the examinee must create a trail joining 1 to 2 and then to 3 and then to 4 etc. until all numbers have been sequentially connected. To take the Test B, the examinee must connect 1 to A and then connect A to 2 and then to B and then connect B to 3 etc. till all letters and numbers are sequentially connected. Upon conclusion of taking the tests, the examiner studies the difference in time for completion of Tests B and A. Several basic results are as follows:

- People take longer to complete the B test then the A test
- The B test requires using two parts of the brain (executive function), the parts dealing with i) numbers and ii) letters; contrastively, the A test requires using just one part of the mind (no executive function) [13]

- Despite the simplicity of the tests, the difference in time between the A and B test can be used to diagnose brain damage and recovery time from strokes [37].

To recap, executive function, that is, using multiple areas of the mind, is a major driver of pedagogic challenge. Startlingly, just using two well-known brain areas is sufficient to create meaningful and measurable cognitive challenge.

ii) Goal-setting refers to skillful graduation of a terminal goal into subgoals each of which is clearly (unambiguously) defined, challenging but achievable in a short time frame. UDL already uses goal-setting, but, this paper advocates explicitly bringing to education and UDL the several decades of research on what works best in the business context [22,23]. A task is maximally goal-set if it possesses 10 attributes: i) specific, ii) measurable, iii) attainable, iv) realistic, v) achievable timely, vi) clear, vii) challenging, viii) complex, ix) has feedback loops, and x) commands commitment. The philosophy of this paper is that there is a commonality between a disinterested poorly performing adult and a poorly performing student with disability.

5. APPLICATION OF THE HIERARCHIES TO UDL

Using the concepts of good pedagogy, or challenging pedagogy, articulated by the hierarchies or Hendel's proposed unification, Figure 5 presents excerpts [38] identifying Dylan's problems that overlap with the executive function and goal setting pedagogic pillars. In other words, Dylan has learning problems because certain pedagogic theories consider certain learning tasks good pedagogy and therefore Dylan *should* learn them. Section 6 will solve Dylan's problems by presenting an alternate formulation of good pedagogy that is sensitive to both good pedagogy in general and vocational congruence.

Dylan's Problem [38]	Classification using Hendel's four pillars
But whereas the Common Core stipulates that 3rd graders should be able to represent and solve multistep word problems involving multiplication and division, Dylan is still working on one-step problems	Executive Function
Instructors use color and enlarged type size to highlight important information in the math word problems they create.	Executive Function, use of multiple modalities
Instructors use explicit instruction to teach word problems in small steps,	Goal Setting
Use manipulatives like Legos and graphic organizers like tape diagrams and number bonds	Executive Function (Kinetic)

Figure 5: Re-formulation of UDL problems and solutions.

6. A VOCATIONAL FORMULATION OF UDL

6.1 Vocational Formulation of Disabilities. This section explores application of the Holland theory to UDL. By using the Holland vocational psychological theory, it will be possible to present guidelines for curricula goals that simultaneously are good pedagogy but also allow for the type of student excellence presented in Section 3.2. The section begins by re-formulating statements about student deficiencies or disabilities in terms of congruence with certain vocational types.

Consider Dylan who, as shown above, has difficulty with multi-step problems. Such a deficiency in performing multi-step problems would indicate incongruity with a future research-type vocation. This example can be elaborated further by considering a student who can learn visually but has difficulty learning abstractly; such a tendency is also incongruous with a research type vocation. This analysis tacitly assumes that a research vocation requires the maximum use of executive function, the ability to integrate and apply multiple approaches to a problem till the approaches yield a solution.

Contrastively, a vocation like hair-styling, seen in the AMIT school mentioned in Section 3, may require an artistic approach vs. an analytic approach. Although any profession will have aspects of executive function, the skills needed for hair styling are different than the skills needed for research. The Holland vocational theory facilitates concretizing this intuition.

Thus, the idea suggested, is to replace speaking about *student* disabilities and deficiencies, with speaking about *vocational* incongruities. This approach is useful, since learning goals are re-formulated in terms of a terminal application of the person's education, to what the person will be doing later on in life.

6.2 Personality Types. One drawback of the analysis made in Section 6.1, is that no distinction is made between preference and ability. Let us further clarify this: Suppose Dylan, despite his present deficiency in performing multi-step problems, wants to, and has a passion, to be a research scientist. This leads to an incongruity between interest and current ability.

Can this incongruity be rectified? More generally, can a basic personality type be changed? The literature provides a possible affirmative answer to changing type in one specific instance.

On the one hand, there is a rich literature stating that the holistic vs. analytic approaches, are intrinsic personality types that cannot be changed. In fact, a recent paper [28] argues that these two types of cognitive processes are embedded in different native metaphysical systems and tacit epistemologies. This paper further speculates that the origin of these differences is traceable to markedly different social systems. The theory and the evidence presented call into question long-held assumptions about basic cognitive processes and even about the appropriateness of the process-content distinction.

On the other hand, the difference between holistic and analytic is precisely the difference between the first two levels in the Van Hiele theory [44]. This assertion can be clarified with standard illustrations of the Van Hiele theory. For example:

- At the holistic level of the Van Hiele theory, students recognize shapes holistically but not analytically. They recognize shape by analogy; they cannot recognize a shape presented in a non-standard setting. For example:
    - A person who has been taught that yield signs are triangular would recognize a triangle in the same position (base on top and vertex on bottom). The person would defend their classification using a holistic argument: "You can see that the shape looks like a triangle because it looks like a yield sign without the word *yield* and is in a different color."
    - Contrastively, if the same person is presented a triangle with its base on bottom and vertex on top, they would be unable to recognize it as a triangle. The

reason they couldn't recognize it is because there is no holistic basis to so recognize.

- However, at the analysis level of the Van Hiele theory, the person would be able to recognize a triangle by its properties. Their defense would reflect analysis of component parts: "That is a triangle because it has three sides." Consequently, they are better able to recognize a triangle in any setting.
- The Van Hiele abstraction level is also illustrative. At the analysis level, although the student perceives objects analytically in terms of their properties, they are not aware of the difference between necessary and sufficient conditions. For example, an analysis-level student, exclusively exposed to triangles with base on bottom, might not classify a yield sign as a triangle; although it has three sides, a necessary prerequisite for triangularity, it does not have its base on the bottom; that is, the analysis-level student might mix necessary properties with extraneous properties. However, at the abstraction level, this deficiency would be gone: A shape is a triangle if and only if it has three sides.

The above considerations motivated Dina Van Hiele to believe that all students can transition (at least in Geometry) from holistic to analytic [43]. This transition can be accelerated with the proper training; it takes approximately 20 lessons to transition from the holistic level to the analytic level and another 50 lessons to transition to the abstraction level. Contrastively, Nisbett, Peng, Choi, and Norenzayan argue that the holistic vs. analytic distinction arises from entire metaphysical systems and epistemologies [28], and therefore cannot be changed.

The 20+50 lessons required to *change* from a holistic to an analytic type basically corresponds to almost a year of instruction (at 45 lessons per semester). Usiskind [42] critically examines the entire Van Hiele theory on a statistical basis with a cohort of about 2700 students. He does not come to a definite conclusion since certain students successfully transitioned from the holistic stage while others did not. However, change of holistic to analytic does happen in certain students.

Summary: This section has reviewed several speculative studies about changing *intrinsic* personality types. There is agreement, that an intrinsic type cannot be changed overnight; if change *can* take place it may require at least a year of work. The evidence is not conclusive.

6.3 Holland Theory [11, 18, 32, 40]. Having reviewed the literature on personality types, this subsection returns to the main task of this section: reformulating UDL in terms of vocational types. The Holland personality theory allows such a re-formulation. Its strength is precisely that it studies the optimum interaction between personalities and environments in terms of preferences and (dis)likes. Although initially conceived as a theory of vocational types, it applies more broadly to personality types and environments. The Holland theory has "contributed profoundly to psychology's conceptualization of people and work environments," "has generated international interest," is considered one of the foremost theories on people and environments, and correlates well with other personality theories.

This theory categorizes each i) person, ii) vocation, and iii) environment as primarily belonging to one of six types labeled Realistic, Investigative, Artistic, Social, Enterprising, and Conventional (collectively labeled RIASEC.). Figure 6 describes these six types. The Holland personality of a person, vocation or environment, is a 3-letter code corresponding to the person's primary, secondary, and tertiary RIASEC categories [15, 18].

6.4 Recommendations. Specific recommendations for applying Holland to UDL are as follows:

- Holland testing: Even in K-12, students should be administered a Holland personality test as a prerequisite for their IEP. Consequent discussions with the student should focus on their understanding of where their vocational preferences lie and what skills they will need. The Dylan hypothetical [38] illustrates this proposal. If Dylan has no *I* (*investigative*) in his Holland personality he should not be required to achieve Common Core goals that are incongruous with his Holland personality; rather, curricula goals should be designed for him (possibly still using Common Core guidelines), that are fully congruous to his Holland personality. If Dylan does have an *I* in his Holland personality, he should be made aware of the need to improve his executive function; his curricula path should provide assistance.
- Research: More research into the possibility of changing *intrinsic* personality types (vs. skills), e.g. holistic vs. analytic personalities, is advocated.
- Public laws: Legislators should explore methods to introduce alternative curricula with vocational components.

RIASEC Code	Holland Personality Category	Brief Description:
R	Real	Works with inanimate things, for example, auto mechanics.
I	Investigative	Experiments with new ideas, for example, scientific researchers, political dissidents, philosophers,
A	Artistic	Works with emotions, for example, poets, musicians, and artists.
S	Social	Works with other people vs. with objects or ideas.
E	Enterprising	Leads other people, e.g. Managers.
C	Conventional	Finds satisfaction in productivity based on routine activities, for example, a call center worker whose goal is a large response rate per day.

Figure 6: Explanation of the Holland RIASEC categories.

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