# A Comprehensive Interdisciplinary Program To Totally Transform Education[1]

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## Abstract

*This chapter provides a comprehensive interdisciplinary program for education, significantly increasing educational success and satisfaction, and solving many current educational problems. The proposed program envisions education as the interdisciplinary interaction of, and communication between, the fields of psychology, vocational counseling, legislative reform, information technology, instructional design, project management, and cybernetics. No method in this chapter is new. Methods advocated in the chapter are derived from successful implementations in various countries or various disciplines. The methods also reflect use of interdisciplinarity to justify a unification of, or supplement to, existing accepted approaches. Each method mentioned in the chapter has significantly solved major educational problems. The main purposes of the chapter are to gather these ideas into one place, and make readers aware of their availability, with the hope that this awareness can lead to a wider applicability of these methods resulting in more educational successes. The chapter covers major current educational areas including, student learning, educational infrastructure, educational research, delinquency and recidivism, motivation, as well as the instruction in traditionally difficult teaching areas including essay writing and verbal mathematical problems.*

Keywords*: executive function, goal setting, attribution theory, self-efficacy, vocational psychology, vocational theory, recidivism, educational infrastructure, Holland, skill competencies, educational software, teaching writing, verbal mathematical problems, educational research*

## 1. Introduction –A Brief History

This section reviews a diverse set of current educational issues, and describes methods of solution applying a vocational approach or using specific features in educational infrastructure. Traditional and new approaches for including cognitive challenge in education are also presented. Both the problems and directions of solution are described. Further details are then provided in subsequent sections.

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### 1.1. The Pedagogic Hierarchies

To use a plant analogy, Abraham Bloom (1956) planted a seed in the latter half of the last century, by introducing his pedagogical hierarchies. The broad idea of the hierarchies is that certain pedagogic material is challenging while other pedagogic material is simple. Challenging pedagogy might involve cognitively higher thinking activities such as analysis and contrast while simple pedagogy might involve lighter-thinking activities such as rote memorization.

Continuing this plant analogy, this seed, over the last 70 years, has blossomed into a mighty tree with diverse branches, exotic flowers, and delicious fruit. The idea of the pedagogic hierarchy was accepted by educators, both those who teach and those who engage in pedagogic theory. Educators quickly realized that instruction and assessment must reflect higher cognitive challenge. Other researchers developed alternate educational pedagogies including those of Anderson-Krathwohl (2001), Gagne (1985), Marzano (2001), and Van Hiele (1986). Along with the hierarchies came a variety of teaching approaches, alternatives to the traditional approach of an instructor lecturing and students passively listening. These approaches include Flipped Classroom (Bergmann & Sams, 2012; Strayer, 2012), Inquiry Based Learning (IBL) (Wallace & Husid, 2011), Project Based Learning (PBL) (Patton, 2012), and Team Based Learning (TBL) (Hills, 2001).

The Universal Design in Learning (UDL) movement also arose advocating that the three areas of i) instruction, ii) assessment, and iii) motivation be tailored to the individual student (Krakower & Plante, 2016; Morrell& Popejoy, 2014; Murawski & Scott, 2017; Nelson, 2014; Noyce & Hickey, 2011; Rapp, 2014; Stein, 2016; Salend & Whittaker, 2017).

Besides the interest in the hierarchies by educators, legislators were also interested in the new theories. In the United States, Congress passed four public laws aimed at requiring teaching accessibility for everyone (Congress, 1998, 2001, 2004, 2008).

### 1.2. Unification of the Hierarchies

The last 20 years has witnessed further research into the hierarchies pointing to an underlying unity. Yazdani (2008), for example, showed that the Gagne and Van Hiele approach both produced equivalent significant improvement in learning; in other words, the specific form of the hierarchy was not as important as the use of *some* hierarchy. Hendel (2017), in a theoretical work, building on the unifying attempts of Yazdani (2008), showed that all pedagogic hierarchies address four pillars of education and it is these pillars

of education which drive pedagogic challenge; the individual hierarchies simply use different words to point to these four pillars.

Hendel (2017) has shown that proper utilization of these four educational pillars can lead to more educational successes in traditionally difficult teaching areas (e.g. writing or mathematical verbal problems), remove obstacles to research, and facilitate instructors applying the known theories. Hendel's four pillars (2017) also allow simply addressing the need for richer educational homework exercises (Hendel, 2010a, 2013). The need for pedagogically challenging homework exercises is highlighted by Hess (2004, 2006) who, half a century after the pedagogic hierarchies were introduced, showed, in a review of several thousand K-12 homework assignments, that the majority of them were of lower cognitive level.

### 1.3. Educational Infrastructure - Disparities and Educational Gaps

Despite the diverse interest from different sectors with multiple approaches within each sector, educational problems persisted. The standards for judging educational success rely on two traditional metrics, performance and satisfaction. The problems that persisted were students not learning, as well as students dropping out of school and getting involved in delinquency problems. Additionally, disparities in education widely existed.

The problem of disparities in education, particularly STEM (Science, Technology, Education, and Mathematics) was the focus of a beautiful study by Clark (2014) who reviewed uniform assessments of education in countries in almost all major continents. This study uncovered four common features that ensured elimination or significant reduction in gap disparities.

### 1.4. The Vocational Approach, Delinquency and Recidivism

The vocational approach employed by the AMIT school network (AMIT(a), NA; AMIT(b), NA; AMIT(c), NA) was successful in almost totally eliminating problems related to lack of student motivation, retention, delinquency, and recidivism. Other countries and governing entities have also successfully used a vocational approach (Career and Technology Programs, NA; Olofsson & Persson, 2014;). The success of the vocational approach is not confined to education; it is emerging as one important treatment approach to mental illness (Bond et al, 2001; Lammerts, Schaafsma, Bonefaas-Groenewoud, Mechelen, & Anema, 2016)

### 1.5. Contributions of this Chapter

The contribution of this chapter is the collection of successful methods from diverse disciplines and different countries as well as a description of the theoretical foundations underlying these successes.

Sections 3 and 4 discuss the potential successes of the vocational approach as well as its theoretical foundations. Section 5 discusses educational infrastructure; the four attributes necessary to ensure elimination or reduction in gap. Sections 6 and 7 present the latest unification of the pedagogic hierarchies as well as their theoretical foundation. It is shown how several difficult educational areas can be successfully approached using this unification. Throughout the chapter, concrete recommendations are presented in connection with the successes discussed.

## 2. Methods

This section discusses the methods used throughout the chapter. The golden standard in all disciplines is the double-blind experiment that eliminates all possible counter-explanations. This is certainly a terminal goal. But intermediate goals frequently precede this terminal goal. Most of the conclusions and recommendations in this chapter fall into this category.

### 2.1. Multiple Successes in Multiple Countries

A very deep method of verification is implicitly offered in the beautiful study by Clark (2014). Clark studied common assessment of STEM (Science Technology Education and Mathematics) in countries from the majority of continents. The study shows that the three countries that excel in STEM education (avoiding a STEM gap) each have four distinguishing characteristics. Hendel (2014a) in a book review pointed out a fourth country that uses these four characteristics. The four attributes will be discussed in Section 5; they represent an infrastructure that facilitates teaching STEM successfully without gaps.

The method implicitly used by Clark (2014) consists of reviewing multiple successes (through a common assessment instrument) in multiple countries. Such a method points to validity in the results. At the very least, such a method prevents a traditional social-science critique that the study is flawed because experiments or observations were restricted to particular localities and cultures.

### 2.2. Interdisciplinarity

A second method used throughout the chapter is application of established ideas in other disciplines to explain reported educational successes. An example will clarify this. Yazdani (2008) demonstrated the equivalence of two particular pedagogical hierarchies in achieving pedagogical success. This led Hendel (2017) to seek the underlying theoretical unification of all the hierarchies. The unification is based on numerous experiments,

methods, and accepted results in the discipline of psychology. This unification simplifies application of the hierarchies. Here, the method consists of use of interdisciplinarity, application of successful methods from another discipline, to suggest a fresh approach in education.

### 2.3. Summary

In summary, this chapter uses as methods, i) multi-country results, and ii) interdisciplinary reformulation of educational issues in categories and concepts well established in other disciplines. While further verification is always encouraged, this chapter establishes a sound basis for using ideas or conducting experiments possibly on a smaller scale.

## 3. The Vocational Approach, the AMIT Technological School

This section reviews a successful attempt to eliminate problems of retention, delinquency, and recidivism, and to turn around students who are 'known to the authorities' into important contributors of society.

### 3.1. The Organization, AMIT

AMIT, Americans for Israel and Torah, is a charity that focuses on education, particularly for disadvantaged children (AMIT(a), NA; AMIT(b), NA). It is one of the educational networks in Israel. It currently runs about 106 schools in about 32 cities for about 41,000 students. It has over 320,000 alumni. In the past few years, it was scored by the Ministry of Education as the most successful educational network, the scoring being done through a variety of metrics. The AMIT network emphasizes partnerships with leading educators in other countries, contributing to its successes.

### 3.2. The Vocational School

This section highlights the AMIT State Technological High School in Jerusalem (AMIT(c), NA). This school focuses enrollment on poor and vulnerable children, who have not met traditional academic requirements, have behavioral problems, have undiagnosed learning disabilities, and are known to welfare authorities. Many students have failed other programs and this school is their last chance.

### 3.3. School Philosophy

The educational philosophy of the school is to concentrate on vocational skills while still meeting basic state curriculum requirements for high-school students, albeit at a minimal level. The school uses professional development as well as social and psychological workers. It seeks to foster

trust and responsibility.

Students entering the school can choose between several vocational tracks including electronics, hair styling, woodcutting and tourism. The school provides a flagship track in automotive repair.

It should be noted that the State of Israel has a matriculation requirement. All students graduating high school must pass a set of matriculation exams to achieve a graduation status. This graduation status is equivalent to a diploma status in other countries and is one factor determining entry into the professional arena, entry into college, and placement in the army.

Although the matriculation exams are uniformly given to the entire country, they span a wide range of areas. Passing can take place on two levels (scores of 4 and 5). This enables a student deficient in mathematical skills to concentrate on other disciplines and seek a minimal passing score in mathematics.

### 3.4. Results

The results are highly positive. Over 95% of graduates serve in the army or for national service. Furthermore, the school has been successful partnering with the prestigious army Technological and Logistic corporation responsible for advanced weaponry for the nation.

Thus, these students, many of whom have been on drugs with behavior problems and have had run-ins with the authorities, graduate as leaders with responsibility for the nation's defense.

**3.5. A Citation**: The following citation (AMIT( c), NA) summarizes the preceding:

> 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, and many are known to the welfare authorities. The school offers them a second chance for success, with a range of vocational topics including auto mechanics, electronics, graphic design and hair styling. The school boasts a very low dropout rate and over half of the students achieve a technological diploma or a *bagrut* certificate upon graduating.
>
> "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 (55% in combat units), and 93% of the females serve in either the IDF or national service.

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 program offers a three-year course in theoretical studies along with practical, hands-on learning in the growing and in-demand vocation of servicing the high-tech cars of today and tomorrow.

The AMIT State Technical High School recently formed a partnership with the Israeli Defense Forces (IDF). Students entering 10th grade can join a unique cadet program with a focus on auto-tech studies. The cadets come to school in uniform and are supervised by army personnel. After graduating, they will serve in the IDF's prestigious Technological and Logistics Corps, where they will be responsible for the development of the most advanced weaponry.

Active educational vocational programs also exist in other countries (Career and Technology Programs, NA; Olofsson & Persson, 2014).

### 3.6. Brief Discussion of Other Applications of the Vocational Approach

Besides being successful in the educational area, the vocational approach is successful in other areas such as treatment of the mentally ill. In the late eighties (of the twentieth century) the idea emerged that successful vocational placement is one alternate approach to therapy (Strauss, Harding, Silverman, Eichler, & Liberman, 1988). This led to formulation of The Individual Placement and Support (IPS) model of supported employment for mentally ill people, the most effective method for creating employment. Although relatively young, it has grown rapidly and has produced a good literature justifying its approach (Drake, 1998).

Several models of vocational training have emerged including the IPS, the Supported Employment Model, and the PSR (Psychosocial Rehabilitation Program). The IPS itself is one form of the Supported Employment Model. The Supported Employment Model is characterized by i) vocational placement in integrated settings with nondisabled workers, ii) ongoing vocational support, and iii) vocational placement based on the patient's current skills (in contrast to an approach that teaches new skills) (Bond et al, 2001).

The IPS model supplements the Supported Employment Model with a client team consisting of employment specialists, case managers, and psychiatrists; the IPS model emphasizes assertive outreach to place clients in normal settings (with other non-disabled workers) outside of a mental health or rehabilitation center (Becker & Drake, 1994).

A further development of the IPS approach, is the *place first, then train* model; clients are *first* placed in a vocational setting and *then* trained as needed, that is, the client is, as soon as possible, placed in a real-world setting with other non-disabled workers rather than in a "rehabilitation program" (Bond & Dincin, 1986). Studies of similar programs in other countries have confirmed the usefulness of the vocational approach for the mentally ill (Lammerts, Schaafsma, Bonefaas-Groenewoud, Mechelen, & Anema, 2016).

One should note the similarities between the vocational approach for the mentally ill and the AMIT Technological school approach; they both emphasize work in prestigious settings with trust and responsibility in the client.

## 4. The Holland Vocational Theory

### 4.1 Overview and Goals

This section presents two formulations from two different disciplines to explain the theoretical foundations for the success story presented in Section 3. These formulations enhance understanding of this success; they also suggest future directions of future applicability.

### 4.2. The Holland Theory

Holland (1997) created a theory of vocational psychology. At a high level, Holland posited that just as people have personality types, so too, vocations and work environments have personality types. Furthermore, people are happiest, most satisfied with their environment, most likely to remain in their current setting, and least likely to change when there is *congruence* between the personality of the person and the personality of the vocation. Conversely, when there is lack of *congruence* between the personality of the person and the personality of the environment, a person is most likely not to be satisfied, unhappy, and seek a change in vocation.

Before proceeding some examples will clarify this approach

Example 1: A person who prefers working with objects versus people, is likely to find greater satisfaction as say a car mechanic than a human- resource analyst, or a pastor, or a teacher. Conversely, a person who prefers working with people is more likely to be satisfied in jobs directly dealing with people such as pastors, instructors, and human resource specialists.

Example 2: Some people may prefer conventional vocations where success at the vocation is measured by the number of successful outcomes per unit of time. As a simple example, a person with a conventional personality type might find greater satisfaction at a call center vocation where job appraisal measures the number of calls answered per day; contrastively, such a person would feel very uncomfortable in a job such as an artist or musical composer where job appraisal is not tied to the quantity of output.

The strength of the Holland vocational psychological theory 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," and is considered one of the foremost theories on people and environments. The Holland theory correlates well with other personality theories (Fruyt & Mervielde, 1999; Holland, Powell, Fritzche, 1994; Oliver & Waehler, 2005; Swanson & Gore,2000).

This Holland theory categorizes each person, each vocation, and each environment as primarily belonging to one of six types: *Realistic, Investigative, Artistic, Social, Enterprising, and Conventional* (collectively labeled RIASEC.).

With this brief introduction, Table 1 lists RIASEC, the six Holland personality types, and brief descriptions of them. Although this description focuses on people, the theory is equally applicable to vocations and environments (Fruyt & Mervielde, 1999).

During diagnostic vocational counseling, people are normally assigned primary, secondary and tertiary Holland codes (Holland, Powell, Fritzche, 1994). Similarly, professions are assigned primary, secondary and tertiary codes. These three-letter codes define the personality type.

Example: A kindergarten schoolteacher might have the personality type ESA. Here the E corresponds to the Enterprise personality type, the tendency of a person or vocation to emphasize leading other

people; the S corresponds to the Social personality type, the tendency of a person or vocation to emphasize dealing with people instead of say objects; and the A corresponds to Artistic personality type and would correspond with the need of a kindergarten teacher to be creative, creating games and projects to motivate his or her children.

The order of the six RIASEC categories (that is, R, I, A, S, E, C) corresponds to the degree of *congruence* between them. For example, the *social* and *enterprising* (leading other people) Holland personality categories are "close" while the *artistic* and *conventional* personality categories (for example a call-center operator whose performance is measured by the quantity of output) are "more distant and lack congruence." As pointed out above, the degree of *congruence* between the person's RIASEC three letter code and the vocation's three letter code is predictive of satisfaction and happiness. Traditionally, the six RIASEC categories are arranged at six equidistant points on a circle. On such a circle *social* and *enterprising* are near each other while *artistic* and *conventional* are diametrically opposite.

**Table 1. Brief Description of the Holland RIASEC Categories**

| RIASEC Code | Holland Personality Category | Brief Description: |
|---|---|---|
| R | Real (Plant / Grain offerings) | The Real personality type is interested in working with inanimate things; for example, people who like to spend time fixing cars and other mechanical devices. |
| I | Investigative (Bird offerings) | The Investigative personality type is interested in experimenting with innovative ideas. The emphasis is on innovation whether socially acceptable or not. Examples of investigative personalities include scientific researchers, political dissidents, philosophers, and rebellious teenagers. |
| A | Artistic (Perfume offerings) | The Artistic personality type is interested in working with creating emotions; for example, people who like to create poetry, musical compositions, and other forms of art. |
| S | Social (Sheep offerings) | The Social personality type is interested in working with other people (vs. say an emphasis on working with objects or ideas). |
| E | Enterprising (Ram offerings) | The Enterprising personality type is interested in working as a leader of other people. Managers are good examples. |

| | | |
|---|---|---|
| C | Conventional (Oxen offerings) | The Conventional personality type is interested in productivity based on routine activities; for example, a call-center worker feels satisfied when a large number of calls per day with satisfactory resolutions are completed. |

### 4.3. Application of the Holland Theory to the AMIT Technological School

To facilitate further familiarity with the Holland RIASEC categories, Table 1 parenthetically inserts next to each Holland personality category the associated biblical sacrifice type corresponding to it. This is based on a contribution of Hendel (2010b) who noted the remarkable coincidence that the six objects offerable in biblical sacrifices correspond rather exactly to the RIASEC categories. For example, *sheep,* an animal that is frequently offered as a sacrifice in the Bible, clearly corresponds to the *social* Holland category, because *sheep* are very social by nature. Similarly *ram,* an animal that is frequently offered, clearly corresponds to the *enterprise* Holland category which describes people who like to not only socialize in their work environment but prefer to lead other people. The point of bringing these offering images is that they succinctly capture intuition; for example, *ram* communicates more to most people then the word *enterprising.* Similarly, *perfume offerings* (incense) communicates succinctly the gist of the Holland Artistic category. Consequently, these images facilitate acquiring intuitive feel for the RIASEC categories. Hendel himself suggests that the Temple offerings functioned as vocational psychological rehabilitation, an idea very similar to what is being proposed in several sections of this chapter.

Using the terminology of Section 4.2, the success of the AMIT Technological School, described in Section 3, can be succinctly explained. The AMIT Technological school, by aligning the student personalities with those vocational personalities *congruent* to the student personalities is able to increase happiness, interest, motivation, and ensure likelihood of continuation. Noteworthy in this particular case is that lack of vocational happiness led many of these students to seek improper sources of happiness on the streets, a desire which naturally dissipated as soon as a legitimate source of satisfaction was provided. This explanation would also apply to the success stories, presented in Section 3.6, of *treatment* of mentally ill people with the *right doses* of vocation.

### 4.4. Universal Design in Learning (UDL)

The preceding sub-section formulates the theoretical basis for the success of the vocational approach of both the AMIT network in Israel and the treatment of the mentally ill, in terms of the Holland vocational theory of

psychology. This section presents an alternate formulation in terms of the Universal Design in Learning (UDL) pedagogic approach (Krakower & Plante, 2016; Morrell & Popejoy, 2014; Murawski & Scott, 2017; Nelson, 2014; Noyce & Hickey, 2011; Rapp, 2014; Salend & Whittaker, 2017; Stein, 2016).

UDL, posits that each individual has a distinct and preferred way of learning. As a simple example, some learners may prefer written instruction while other learners prefer auditory instruction; still others may learn tactically from projects. UDL advocates tailored individual treatment in three areas i) instruction, ii) assessment, and iii) motivation.

The contribution of this chapter is to add a 4th area: iv) the actual curriculum. To understand this, note, that, say, in the United States, a high school diploma reflects a certain mastery of topics including mathematics, writing, and a variety of other topics. While states may differ in the intensity of these topics, all states agree that this is *the* curriculum. In other words, there is an understood assumption that all individuals need the same curriculum. This chapter follows Hendel (2019a, 2019b) advocating applying the UDL principles to tailoring the curriculum itself to the individual.

This modified UDL approach explains the success of the Israeli model presented in Section 3. To achieve high school matriculation status in Israel a student must pass a variety of matriculation exams. About half a dozen of these matriculation exams are compulsory. The student has the option of passing exams at one of two levels. To achieve matriculation the student must take at least one exam at the highest level and achieve a certain number of points from all tests combined. In this way, curriculum is tailored to the individual. For example, if a student is not "good" in mathematics, the state requirements do not require passing the mathematics matriculation exam at the highest level. The vocational schools build on this model by adding vocational tracks in other subject areas; as noted in Section 3, these vocational schools have significantly reduced recidivism.

### 4.5. Application of the Theoretical Foundations

Using the two theoretical foundations presented above, the successes described in Section 3 can be elegantly explained. It emerges that the AMIT vocational approach and the vocational treatment of the mentally ill are successful because *congruence* was established between the students or patients and their vocational environment; that is, the environment was tailored to the individual. In the case of the AMIT Technological school, this application of vocational theory manifested itself by tailoring curriculum to the individual, consistent with the Universal in Design Learning principles.

### 4.6. Recommendations

Based on the above theories, this chapter makes the following recommendations:

- The opportunity for vocational assessment should be made available (possibly through existing school staff, and thus not requiring hiring additional staff) at all school levels: K-12, college, and the university.
- Legislation should require at all levels, K-12, college and university, the availability of multiple tracks of curriculum. Graduation requirements should similarly reflect multiple tracks of curriculum.

- Curriculum should be tailored to the individual. The curriculum subjects and the student personalities should be *congruent.* As a simple illustration, a student whose personality is not congruent with mathematics (that is, (s)he doesn't like the subject and the subject is not interesting to them) should not be required to show mathematical proficiency at the highest level in order to obtain graduation status. Similarly, a student whose personality is not *congruent* with the Social type (the biblical image of *sheep*) should not be required to learn teamwork (or alternatively, should be required to learn teamwork albeit at a minimum level).

- Students, parents, faculty, and law-enforcement officers should be made aware of the basic vocational personality types. The implication of this approach is that a counselor or school official treating a delinquency problem at the school level should be aware that lack of *congruence* may be the primary cause. Similarly, law enforcement individuals should be aware of this approach. The familiarity of students and parents with the vocational approach will encourage students and parents initiating requests for correction for rectification of *congruence* problems.

## 5. Infrastructure Facilitating Elimination of Gaps

### 5.1. Overview and Goals

The fundamental thesis of this chapter is that many major educational problems have been solved in some discipline and some country. Therefore, the chapter's goal is to bring awareness of these successes. In the last few sections, the chapter has covered the skillful integration of a vocational component into the educational experience. This section presents the infrastructure needed to eliminate gap disparities particularly in Science, Technology Education, and Mathematics (STEM).

As described in Section 1, Clark (2014) distilled four key attributes needed in education infrastructure to eliminate disparities and gaps. These four attributes are the common features derived from an ambitious review of school systems on the majority of continents. Clark (2014) uncovered three countries, (South) Korea, Finland, and Singapore, to which Hendel (2014b) added a fourth (Israel)), which have eliminated or severely reduced gap in STEM. The four attributes shared by these four countries are: i) the professional treatment of teachers, ii) uniformity in curriculum, iii) uniformity in assessment, and iv) centralized educational oversight. These four areas will be discussed in further detail in Sections 5.3-5.6.

## 5.2. Recommendations

As a consequence of the results presented later in this section, this section recommends specific actions by country legislatures. It is their job to assure that the key attributes discussed in these sections are available, accessible, and adequately funded.

## 5.3. Treatment of Teachers

The fundamental idea is that countries which have eliminated (or reduced) STEM gaps, treat teachers as professionals, the same way doctors and engineers are treated. More specifically, the teacher is perceived as having achieved a professional status through an intensive program of education and accreditation.

The most immediate implication is that the teachers (in K-12 as well as the University level) have majors in the field they are teaching. They also have attained several certifications.

The static nature of a degree or certification is balanced by the dynamic nature of continuing education. The four countries involved all provide teachers with numerous educational opportunities as well as links with universities.

The links with universities are of particular importance since, as will be shown in Section 7.2, links with universities are one component of facilitation of educational research that neither requires extensive planning nor elaborate funding.

The final aspect of treatment of teachers in these four countries is the broad definition of teachers which includes both the actual instructors of classes as well as a network of mentors and tutors. The importance of mentors and tutors cannot be underestimated. They address constraints on teachers who operationally cannot be present continuously. Their presence allows meaningful continuation of instruction outside the classroom. Additionally,

their presence facilitates openness with students; students typically feel more comfortable asking peers such as tutors and mentors for help rather than their instructors. Finally, tutors and mentors are more suitable as role-models. A tutor or mentor is more likely than an instructor to share personal difficulties and failures with students. This sharing is a key component of *role-models* which as shown in Table 4 in Section 6.6 is one of the main drivers of *self-efficacy*, the primary determinant and predictor of successful student learning.

### 5.4. Uniform Curriculum

The four countries without gap disparities each have uniform curriculum standards. These curriculum standards emphasize higher order thinking. This uniformity in curriculum standards, does not contradict the principle, discussed in great detail in Section 4, that this chapter also advocates diversity in curriculum; rather, sufficient multiple tracks should exist for catering to a diversity in student interests and consistent with facilitating *congruence* between students and educational environments. Thus although the curriculum has multiple tracks, each of these tracks should be uniform for the country. This also means that the terminal goals of completion, including assessment, should be the same for all students that take a specific track. Within each track and each particular school, instructional delivery to students should be tailored to individual situations.

The following anecdote, related at a private charity event which the author attended, illustrates the challenges of uniformity and suggests remedies for how these challenges should be dealt with. The anecdote relates one incident in Operation King Solomon, the airlifting of several thousand Ethiopians to Israel and the challenges of fully integrating them into Israeli society. Many Ethiopians attend schools in the AMIT network discussed in Section 3.

> The AMIT head of research and development visited one of these schools teaching Ethiopian immigrants. She explained the uniformity requirements for all schools in the AMIT network. The principal, rather incredulously responded, “But these students are Ethiopians; they come from severely disadvantaged homes in another country; surely exceptions can be made to the uniformity requirements to accommodate the special needs of this very unusual situation.” The head of R&D politely responded that there are no exceptions to uniformity.
>
> She relates, “No sooner had I left the high-school, did I receive a text message from the Director General of AMIT advising me of a complaint by this principal to what he considered non-achievable standards.”

However, the insistence on uniformity prevailed. The Ethiopian students did exceptionally well on the country-wide matriculation exams. (In passing, AMIT Ethiopian graduates have achieved important positions in Israeli society and the army).

The head of R&D when relating the story, explained that the special needs of the Ethiopian students, while not met by changes in curriculum, were met by increased mentoring and tutors.

This story highlights the importance of these common four attributes shared by the four countries that excelled in eliminating gap disparities. The anecdote also illustrates how the four attributes synergistically integrate; in the story just cited, the availability of a strong mentor-tutor network, a requirement for teaching, successfully, compensated for a possible challenge to uniformity in curriculum

### 5.5. Uniformity in Assessment

For uniformity in curriculum to be meaningful, the vehicles for assessment must also be uniform. In Israel for example, the high-school matriculation exams are uniform throughout the country. This is fully consistent with the multiple curricula tracks since there are in fact multiple matriculation exams. As indicated in previous sections, there are two levels of passing for each matriculation exam; students, to achieve matriculation status, must score highest in at least one matriculation exam and have an aggregate of several exams passed at some level.

These scores on these matriculation exams determine a wide variety of entry possibilities for the students including placement and entry in colleges, universities, professions, and army programs. Thus there is a simultaneity of uniformity and diversity.

### 5.6. Uniformity in Oversight

Clearly, one cannot have uniformity in assessment and curriculum unless there is uniform oversight. If two different bodies assess or define curricula, even if they share goals there will be differences. In Israel, the administration of assessment is governed by the Ministry of Education. The finalization of curricula is a two-part process: The Ministry of Education defines the syllabi connected with the various matriculation exams; each network of schools then adopts these curricula to its own system. However, assessment by the matriculation exams, is both required and uniform.

As already indicated, different schools may teach different tracks. Thus a comingling of uniformity and diversity is present throughout the educational process.

## 6. Unification of the Pedagogical Hierarchies

This section presents a unification of the diverse pedagogical hierarchies based on a theoretical framework rooted in psychology.

### 6.1. Problems with the Current Hierarchies

As described in Section 1, a key tool for successful pedagogy is the use of a hierarchy, a list of levels of teaching and assessment starting at a low level, mere rote learning, and culminating at higher levels involving higher cognitive thinking. Such hierarchies allow instructors to assess their lessons and assessment vehicles to ensure rich pedagogy. Towards this end there are several available hierarchies, such as those of Anderson-Krathwohl (2001), Bloom (1956), Gagne (1985), Marzano (2001), and Van Hiele (1986)).

This section presents a unified approach to these hierarchies, that is, a set of concepts, fully consistent with each of the hierarchies but much easier to apply. Hendel (2017) continued the work of other researchers who showed an underlying commonality in the hierarchies; for example Yazdani (2008) showed that use of either the Gagne (1985) or Van Hiele (1986) hierarchy led to similar classroom improvement. Hendel (2015a, 2017) proposed a theoretical unification based on psychological processes.

The importance of the Hendel hierarchy is not only in its intuitiveness, that pedagogic challenge corresponds to general psychological challenge, primarily executive function, but rather in its ease of use. As will be shown, to implement the Hendel hierarchy one asks the question, "How many modalities of the mind are used in this teaching or assessment?" Thus the identification of cognitive challenge is reduced to mere counting.

Prior to presentation of the Hendel hierarchy in detail, it is worthwhile to emphasize problems with the current hierarchies. Hess (2004, 2006) in an interesting study, collected several thousand homework assignments from K-12 and analyzed them in a matrix whose rows and columns used the levels in the Bloom-Anderson hierarchy (2001) and the levels in the Webb (1997, 1999) depth-of-knowledge categories. Hess deliberately used two hierarchies to ensure that negative results were not biased by the particular hierarchy used.

The study showed that K-12 homework was significantly deficient in pedagogic challenge; that is the homework was classified by both the Webb and Bloom-Anderson hierarchies as involving lower order thinking skills.

This study was performed about 50 years after Bloom published his hierarchy (contrastively, the Webb hierarchy was new). The theoretical problems with using the hierarchies are two –fold. First, as has been amply pointed out, the typical instructor (say in K-12 but also in the college and the university level) does not have the talent to create cognitively challenging problems, where cognitive challenge is defined by the hierarchies (Stecher & Mitchell, 1995; Tomlinson, 1999). Many typical textbooks contain a preponderance of "low level" problems. Thus assessment resources for homework is a serious challenge. However, there are books suggesting meaningful ways of extending known problems and making them more challenging (Brown & Walter, 2005). Hendel (2010a, 2013), basing himself on actuarial-exam questions, pointed out that two-step problems (TSPs), problems with at least two components, are challenging in the precise sense that they involve executive function and analysis, but are nevertheless rather easy for any instructor to create. The use of TSPs is discussed in Section 7.4.

A second theoretical problem with the current hierarchies is training; the hierarchies do accomplish the goal of instruction and assessment that are pedagogically challenging, but only if one is sufficiently trained in them. Although all hierarchies are intuitive, their mastery still requires training. The following example illustrates why training is needed.

> Consider *analysis* in the Marzano taxonomy (2001). *Analysis* reflects a higher cognitive level. But how does one recognize that something is classified as *analysis*? The Marzano theory says that the analysis level is attained if it is classified in one of five categories: *comparison, contrast, error detection, classification, and sorting.* Thus to successfully apply the Marzano theory one must have these five categories on one's fingertips and be able to recognize them. All this requires training and practice which not all instructors have gone through. The training is not particularly difficult; but one must learn a sequence of words describing each level, and then further words describing sub-levels.

## 6.2. The Hendel Hierarchy

Hendel's (2015a, 2017) hierarchy consists of the four educational pillars, that is, drivers, of educational excellence. They are

- Executive function
- Goal setting
- Attribution theory

- Self-efficacy.

Each driver is briefly explained below in its own section. Applications of the theory are presented in Section 7.

### 6.3. Executive Function

Executive function refers to the brain function that allows a person to simultaneously use and integrate several other brain functions. There are many aspects to executive function and there are many different tests of executive function such as the open-ended executive function tests and performance executive-function tests (Toplack, West, & Stanovich, 2013). Performance executive function tests assess performance in an examiner's office.

Hendel (2015), reviewed several performance tests, and showed that all performance tests assess a person's ability to predict outcomes based on Boolean functions (attributes combined with *and, or, and not*.) A simple consequence of this principle is that an activity fulfills the executive function criteria if either:

- It has multiple parts (an illustrative question consisting of two parts is the following: *3 plus a number equals 7; what is the square of that number*), or
- It uses multiple modalities of the mind such as formal, visual, computational, and verbal (Hughes-Hallet et al, 2013).

Although Hendel (2015, 2017) introduced the application of the idea of using multiple modalities to unify the concept of higher cognitive level of pedagogy in several hierarchies, the idea and importance of multiple modalities is common in the educational literature and advocated in several educational standards spanning K-12 and the college-university level (Hughes-Hallet et al, 2013; Kendall, 2011; NCTM, 2000).

Applications of the executive function principle to difficult educational problems are presented in Section 7.

### 6.4. Goal setting, Measurability, Specificity

Goal setting refers to how a complex task is broken into component tasks. The literature lists as many as ten identifying criteria for good goal setting. When breaking down a complex task into component tasks, best learning and performance are attained when the component subtasks are:

- Specific,
- Challenging,

- Realistic,
- Measurable, and
- Attainable in a short time (Lenz & Shortridge-Baggett, 2002; Locke, Shaw, Saari & Latham, 1981).

In such a case, one can also say that the component subtasks are *measurable* or *specific*. The mnemonic traditionally used for describing such a sequential analysis is S.M.A.R.T:

- *S*pecific
- *M*easurable,
- *A*ttainable
- *R*ealistic
- *T*imely achievable

Locke and Latham (1990) add five other attributes for best goal setting:

- Clarity,
- Challenge,
- Commitment,
- Feedback
- Task Complexity

Hendel (2017) points out that these attributes can be conveniently summarized using three descriptors: A task manifests good goal setting (that is good subgoals) if it possesses the following three attributes:

- *Easy identification* (also known as *clarity, specificity, measurability*): Each subgoal can be quickly and easily identified (for example a good composition is not something easily identified; contrastively, asking whether the topic sentence (theme) of a paragraph relates to other paragraph sentences by one of several methods such as "example", "cause" "effect" is more transparent. )
- The subgoal *is attainable timely,* in a short amount of time
- The subgoal is *challenging* (it is not something one can just do; considerable effort must be used)

The following contrast from a beautifully designed set of experiments by Zimmerman and Kitsantis (1996, 1997) and Kitsantis and Zimmerman (1998) illustrates good and poor goal setting:

- One group of students being trained to throw darts were told as a goal, "Achieve the highest score (the greatest number of hits) possible."
- Another group of students being trained in dart throwing were told to go through three steps prior to shooting darts: *proper position, proper aim, proper throw* (each of these being explained in detail to the students)

The second group scored significantly higher than the first group. Although both teaching methods used easily identified goals and both were challenging, only the second method was achievable timely (students could for example practice the proper position till it was attained; contrastively, there was no easy method to achieve a high score (it could take a short time or long time). Another perspective to explain the contrast in treatments of the students is that the goal achieving a "high score" was not broken down into chunks each of which is timely attainable. Still another formulation of the explanation is that the goal of achieving a good score is not *clear* and *specific* while achieving a specific throwing or aim position is *clear* and *specific.*

### 6.5 Attribution Theory

Several researchers in different areas have rediscovered attribution theory (Dweck, 1986; Orbach, Singer, & Price, 1999; Weiner, 1985).

Roughly speaking, attribution theory studies how an individual explains his or her successes and failures; in other words, attribution theory classifies the causes that a person attributes to success or failure. Three dimensions of attributions of success and failure – *internality, stability, and controllability* – are presented in Table 2 with descriptions and examples.

**Table 2. Three Dimensions of Drivers of Success and Failure**

| **Dimension of Success or Failure** | **Value of Dimension** | **Examples** |
|---|---|---|
| External/Internal | Driver is *external* to the person. | I failed because the *instructor* didn't *like* me. |
| External/Internal | Driver is *internal* to the person. | I succeeded because *I* worked; I succeeded because *I* am a genius; I failed because *I* am a failure. |
| Stable/Unstable | Driver is *stable* and will remain the way it is. | I succeeded because I am a *genius*; I succeeded because everyone knows my *family name.* |
| Stable/Unstable | Driver is *unstable*; it must be maintained or it will go away. | I succeeded because I *guessed.* |
| Controllable/ Uncontrollable | The person can *control* the cause of | I succeeded because I put in five hours of |

| | | |
|---|---|---|
| | success or failure. | *effort* |
| Controllable/ Uncontrollable | The person cannot *control* the cause of success or failure | The teacher grading the exams felt like doing me a favor. |

Four typical attributions of success and failure in many students are *luck, ability, effort, and task difficulty.*

Attribution theory shows that superior student performance is achieved if the student attribution of success has the desired properties of *internal*, *stable*, and *controllable*. The typical successful attribution of success is effort and work since i) this is *controllable*, that is, the student can control whether they work, ii) it is *stable* in the sense that the results attained by working are stable (with continued practice), and iii) *internal*, that is whether the student works depends on themselves, not on some outside authority.

Butler (1988) presents the following pedagogic experiment, illustrative of application of attribution theory. Three evaluation treatments were given to three classes studying the same subject. These treatments are presented in Table 3. Attribution theory predicts that the internal controllable attribution affects performance the best, and indeed, the students receiving *comments without letter grades* improved in performance the most since the evaluation comments recommended specific activities for students to improve (*internal, controllable and stable*) and were not external, for example, a *grade* given by someone else and not having future relevance to the student.

**Table 3. Three Evaluations of Homework in Identically Taught Courses**

| **Evaluation Treatment** | **Brief Explanation** | **How this Evaluation Method Is Perceived by the Student** |
|---|---|---|
| Grades | One group was simply given letter grades. | The grade is something external to the student; the grade is given as is without explanation of why the grade was earned; the grade reflects the instructor's opinion. No future action on the part of the student is requested. |

| | | |
|---|---|---|
| Comments | One group was simply given comments, an explanation of why certain parts of the student work were good and why certain parts of the student work were not good. Comments included recommended steps to improve. | Contrastive to the letter grade, the comments reflected attributes that were *internal* and *controllable* since their implementation can be done by the students (controllability). The comments reflect standards accessible to all and not the *opinions* of a grader. |
| Grades and comments | Both a letter grade and comments explaining what is good and bad and how to improve were given. | Although the comments reflect universal standards, the grade reflects the instructor's perception of the seriousness of these standards. Hence, the evaluation is perceived as partially external. |

### 6.6 Self-Efficacy

Self-efficacy is a person's belief that he/she can organize and integrate his/her current skills to achieve certain goals. It is a specific form of confidence, the belief that for certain tasks the person performing the task will achieved the desired goals. Self-efficacy should not be confused with certain related items, such as a person's aspirations and hopes or a person's awareness of his/her skill sets. Self-efficacy is more than the belief that a person can succeed; rather, it is the belief that one can organize and integrate one's current skills and knowledge to perform or succeed at a specific task (Bandura, 1977, 1997, 2000, 2001).

Self-efficacy is important because it is "the core agentic factor that determines people's goal directed behavior" (Feltz, Short, & Sullivan, 2008, p. 5). For example, surprisingly, *knowledge* of self-management skills in diabetic patients does not predict success in self-management; contrastively, in the majority of patients, *self-efficacy* does predict success in self-care (Lenz & Shortridge-Baggett, 2002).

Self-efficacy is the primary determinant of people's levels of motivation to accomplish a specific goal. A high level of motivation is especially needed in complex problem solving since without motivation, problem solvers give up.

To properly apply self-efficacy in educational settings requires understanding its drivers. Self-efficacy and its drivers are well understood.

Self-efficacy is widely used in a variety of areas, for example, sports skill acquisition (Feltz, Short, & Sullivan, 2008) and acquisition of self-management skills by the sick (Lenz & Shortridge-Baggett, 2002).

Bandura (1977, 1997, 2000, 2001), the founder of social cognitive theory, listed four primary drivers of self-efficacy. Maddux (1995) and Schunk (1995) supplemented these four drivers with two more. Not all six drivers are equally important. The most important driver of self-efficacy is previous *performance successes*. *Vicarious experiences* and *verbal persuasion* are also important drivers, but play a secondary role. The other drivers play a tertiary role. Self-efficacy increases the most when drivers are combined (Feltz, Short, & Sullivan, 2008; Lenz & Shortridge-Baggett, 2002). The six drivers for self-efficacy are presented in Table 4 with brief explanations.

**Table 4. The Six Drivers of Self-Efficacy with Brief Explanations**

| Driver of Self-Efficacy | Brief Explanation |
|---|---|
| Performance accomplishments | The more successes one has had, the greater one's self-efficacy in future successes; the influence of pass successes on self-efficacy is a function of i) performance difficulty, ii) the effort expended, and iii) the amount of guidance needed. Performance accomplishments can also be facilitated by guided coaching. |
| Vicarious influences | Self-efficacy is strengthened through observation and comparison with others. Vicarious influences include observations of masters, observations of entire acts or specific act components, comparison with peers attempting to achieve the same goals, and even self-modeling, for example, videos of one's entire successful past performances or important parts of them. Vicarious influences are best when the role model i) fails, ii) struggles, and iii) overcomes failure. |
| Verbal persuasion | Self-efficacy is strengthened through verbal persuasion, evaluative feedback, self-talk, and expectations of others. |
| Physiological information | The general rule is that, when the individual perceives positive physiological states as resulting from study or training, self-efficacy improves; conversely, when negative physiological states such as anxiety, |

| | |
|---|---|
| | headaches or discomfort are associated with study or training, self-efficacy decreases. |
| Emotional states | The general rule is that, when the individual perceives positive emotional states as resulting from study or training, self-efficacy improves; conversely, when negative emotional states such as anxiety or discomfort are associated with study or training, self-efficacy decreases. |
| Imaginal experiences | Self-efficacy is improved through imagining oneself succeeding, practicing, or even imagining oneself confident. |

## 7. Applications

This section presents several illustrations, applying the four educational pillars to educational tasks that are considered challenging. It is shown how the four educational pillars facilitate application and resulting success. The five areas presented respectively in Sections 7.1 through 7.5, are teaching essay writing, educational research, solving verbal mathematical problems, creating pedagogically challenging homework problems, and increased efficiency in student diagnostics and advising. It is hoped that these examples will inspire similar solutions to difficult educational activities in other areas.

### 7.1. Essay Writing

Traditionally, good essay writing is considered non-mechanical; students either have the ability to write or don't have this ability. The idea that good writing can be taught to everyone is not universally accepted.

In terms of Hendel's four pedagogic pillars, the challenge in essay writing is *goal setting*. No one disputes that writing an essay is not a unit skill. The principles of goal setting presented in Section 6.4, requires that any item taught be decomposed into a sequence of activities that are each i) timely achievable, with ii) processes and outcomes that are clear and immediately identifiable, and iii) challenging. The dart-throwing example mentioned in that section is illustrative. To recap the implications of this experiment:

- You can't teach good dart-throwing by telling students, "Try your best; try to hit as many targets as possible."

- You can however achieve good dart-throwing by teaching component skills like *position, aim, and throw*. Such a well-defined goal setting leads to both significant student performance and student satisfaction.

By analogy:

- One can't teach essay writing by telling students, "Do your best; try and achieve as many good writing elements as you can."
- One also can't teach essay writing by emphasizing a mythical creativity that is needed to create spark and dazzle.
- But one can teach essay writing by
  - Clearly identifying component skills that are achievable
  - Providing adequate practice exercises to achieve these skills

It follows, that to achieve good essay writing an instructor needs a teaching resource that accomplishes the goal setting just mentioned. The Jones and Faulkner (1977) approach to essay writing excels in goal setting. Jones and Faulkner (1977) developed these ideas after teaching for many years and grading literally thousands of essays. Based on their experience, they created a clear set of specific goal-setting paradigms accompanied by exercises.

At a high level, the goal setting of Jones and Faulkner (1977) is accomplished by enumerating four main methods to link sentence pairs and five main methods to develop paragraphs. They also present several templates for combining paragraphs into essays. For illustrative purposes, one or two examples are given. The four sentence-pair methods are:

- Enumerative meaning
- Equal meaning
- Subsidiary meaning
- Dominant meaning.

Each of these skills, for example the *equal meaning* skills, is broken up into further skills on how to relate sentence pairs. *Equal meaning* can be achieved by the following five methods relating two sentences:

- Definition
- Amplification
- Sample item
- Supporting data
- Cause and analogy.

Each of these component skills is strengthened by specific illustrations and numerous exercises. The mastering of paragraph types and essay types is similarly accomplished through specific exercises.

The key point here, is that a response to a weaker essay writer is always an emphasis on acquiring specific skills by doing specific measurable tasks that can be mastered in a short time. The exercises to achieve mastery are there. Furthermore, they afford diagnosis. A student is never told, "You lack innate writing ability;" rather they are told that certain specific skills are needed for them to become good writers.

### 7.2. Research without Funding

The tree-diagram method (Nair et al., 2012) is a visual-graphical method designed to improve writing. It is briefly described in the bulleted list below. This is followed by a discussion on how this research developed without a need for funding or an elaborate project. It is hoped that this chapter will inspire similar research endeavors. The basic methodology of the tree-diagram method is as follows:

- A writing theme is given.
- The student circles the writing theme on a piece of paper.
- The student then decides on a few ideas to develop this theme.
- Each idea is written down, circled, and connected by a line to the theme idea.
- Each of the development ideas is then, if warranted, further developed with other ideas.
- These ideas are also written down, circled and connected to the theme development idea they develop.
- The themes and developments are typically expressed in one to three-word phrases.
- The entire piece of paper with circled ideas has a tree-like structure with the theme as the root.
- The paper with the tree-like structure is then used as a basis for writing a full essay.

The tree-diagram method excels at two of the four educational pillars presented in this chapter:

- **Executive Function:** The tree-diagram emphasizes executive function since it approaches writing using two brain areas, writing and visual.

- **Self-Efficacy:** The authors (Nair et al., 2012) emphasize that using the tree-diagram method gives students a sense of mastery and control and increases their self-efficacy. They beautifully describe a paradigm of a cycle that leads to self-efficacy This sequence is presented in Figure 1.

*Teaching* the method ➔
Student *practice* of the method ➔
Student *mastery* of the method ➔
*Anxiety reduction* (because *mastery* has been achieved) ➔
*Increased writing* both in and out of class (because *anxiety* is reduced) ➔
*Increased mastery* resulting from increased performance

**Figure 1.** A six-step paradigm cycle leading to self-efficacy

This paper is in effect a research project. But it didn't require approval, funding, or project planning. As related in this paper and papers on which this is based, the following sequence of events occurred.

A. Discovery: The statement, of the tree-diagram idea was found mentioned in passing in a book on essay writing (Smalley, Ruetten, & Kozyrev, 2000). The idea was not further developed there.

B. First Attempts: Lee (2004) found the idea interesting and tried it in the classroom. As a basis for his decision to explore the method, Lee (2004) emphasized use of two areas of the brain, the visual and verbal.

C. Collaboration: Nair et al. (2012) built on what Lee (2004) had published and did the following: further developed it, collaborated with high schools and a university, and rigorously tested it using statistical methods. Besides emphasizing the visual aspects of the method, Nair et al. (2012) emphasized the improvement in mastery (self-efficacy) and motivation. The testing involved collaboration with other high schools and universities.

D. Experimental: Nair et al. (2012) indicated that the results were still "experimental," indicating that other instructors or institutions may wish to further pursue the method.

This four-step process *discovery-first-attempts-collaboration-experimental* is illustrative of how good research leading to improvement can happen with neither funding nor official projects. We repeat immediately below the overview of this four-step process with an eye to applying it more widely:

A. Discovery: There are many ideas in many books simply ready to be cultivated. The important thing is to be able to *recognize* the good ideas, the seeds, that will blossom into pedagogic improvers. In this case, the utility of the idea mentioned in the textbook could have been easily identified since it involves *executive function*, using *two* brain *modalities*, the visual and motor activities (writing). Such ideas are almost always fruitful. Notice, that the four educational pillars are instrumental in identifying good ideas.

B. First attempts: One need not spend an entire semester on an idea. Typically, one can sneak a technique into one or two lessons. Sometimes, the idea can be used in office hours when students come from help. Such first attempts help identify what is right and what is wrong and whether further study is warranted.

C. Collaboration: One does not need funding; rather, one needs interest. Most university professors are willing to assist in a project like this if they can get a paper out of it. If one has a network of schools they are connected with, typically a few instructors at a few of these schools are interested in trying something out. At this point, one needs cooperation of the principals; but if there are first attempts and university collaboration, this is not difficult.

D. Experimental: A study need not be final and comprehensive. *That* would indeed require extensive planning and funding. It is sufficient to make a well-designed experiment with a sufficient number of students to ascertain if improvement takes place. Such experiments should always have both a quantitative and qualitative component (evaluations of student satisfaction as well as performance are important in research).

### 7.3. Verbal Mathematical Problems

This section illustrates the application of the executive-function educational pillar to facilitate teaching mathematical verbal problems (Hendel, 2014a). The author has found this approach successful in enabling students with verbal problem difficulties to overcome these difficulties. Algebraic modeling of verbal problems, and in fact, modeling in general, is a primary example of higher order thinking skills and is frequently mentioned in discussions of educational reform (The Common Core Standards, NA; Kendall, 2011; NCTM, 2000).

In terms of the four educational pillars, a key point to emphasize about modeling is that it requires a continual multi-dimensional processing of the two brain areas dealing with algebra and language. Tables 5 and 6 illustrate and emphasize the continual verbal-formal interaction by analyzing a simple verbal problem that can be modeled by simple algebraic equations. It is the continual connection of these two processes each simple in their own right, that makes the problem hard and challenging because it now involves executive function.

The verbal problem modeled is as follows:

Amy purchases 4 peanut bags and 1 quart orange juice for a total of 6 dollars. Bonnie purchases 1 peanut bag and 4 quarts of orange juice for a total of 9 dollars. How much does 1 peanut bag and 1 quart orange juice each cost?

Letting $P$ and $Q$ be variables equaling the number of peanut bags and quarts of orange juice purchased, the above verbal problem can be modeled by the following system of equations.

$$4P - 1Q = 6$$
$$1P + 4Q = 9$$

Thus far, the executive function pillar has been used to describe *why* modeling verbal problems is challenging and difficult. Next, it is shown *how* to apply the executive function pillar to successfully teach solving verbal problems. The key idea is to teach using the executive function pillar.

To teach verbal problems, the following procedure is used. First, the idea of an "algebraic-language" dictionary (as presented in Table 5) is presented to students. The meaning of the table should be transparent. Certain keywords are "translated" into algebraic symbols. For example, *and* typically is translated into the mathematical operation of "+". Similarly, words like *is* or *total* translate into an equal sign "=".

**Table 5. Excerpt from a Verbal-Algebraic Dictionary**

| **English Phrase** | **Mathematical Correspondent** |
|---|---|
| And | + |
| For a total of | = |
| Number followed by noun e.g. 4 quarts of orange juice | Number * Noun symbol e.g. 4$Q$ |

Students, under coaching of the instructor, then practice both constructing and using a verbal-algebraic dictionary. Finally, students are asked to take a verbal mathematical problem such as found in the left-hand column of Table 6, and model it into a system of equations, such as found in the right-hand column of Table 6, by applying the verbal-algebraic dictionary presented in Table 5. In constructing and applying such tables, they are read both vertically, column by column, as well as horizontally, row by row.

**Table 5. Verbal-Algebraic Correspondence: Verbal-Problem Modeling**

| **English** | **Math** |
|---|---|
| Amy purchases | |
| 4 Peanut bags | 4$P$ |

| | |
|---|---|
| And | + |
| 1 quart orange juice | 1*Q* |
| for a total of | = |
| 6 dollars | 6 |
| Bonnie purchases | |
| 1 peanut bag | 1*P* |
| And | + |
| 4 quarts orange juice | 4*Q* |
| For a total of | = |
| 9 dollars | 9 |
| How much does | Solve for |
| 1 peanut bag | *P* |
| and 1 quart orange juice | *Q* |
| each cost? | |

Although the system of algebraic equations has to be solved, this is a manipulative exercise and is masterable with sufficient practice. The hard part of the verbal problem is the translation of the words into algebraic equations.

The success of this method is that it gives students with poorer ability a tool, handle, or method by which to solve these problems. This method when mastered increases self-efficacy, with a consequent reduction in math anxiety. This in turn leads to more practice, more success and more mastery. Both the method, exploiting the executive function educational pillar, and the increase in self-efficacy are virtually identical to that found in Figure 1 in connection with writing.

### 7.4. Pedagogically Challenging Homework Problems

First, this section reiterates the pedagogic issue with homework assignments uncovered by Hess (2004,2006). Hess reviewed several thousand homework assignments in K-12 and graded them according to two pedagogical hierarchies, that of Bloom-Anderson (2001), and Webb (1997, 1999). The study showed that despite the widespread use of the pedagogic hierarchies, homework invariably was low level.

In the following decade, there was a focus on creative problem writing, on the part of both students and instructors, as a method of enriching course pedagogy. This focus has taken several directions. Some papers focus directly on methods of creative problem writing (Brown & Walter, 2005; Contreras, 2007; Crespo & Sinclair, 2008) while other papers focus on the nature and attributes of good problems (Crespo & Sinclair, 2008; Stecher & Mitchell, 1995).

The "creative problem writing" approach has branched in two directions. One direction advocates creativity through exploration, relevant real-world settings, experimentation, and a skillful study of changing problem hypotheses (Brown & Walter, 2005). Typical exercises in creative problem solving could involve, for example, hypothesizing patterns in a sequence of numbers or a geo-board, or modeling a real-world setting. A particularly interesting technique for creative problem solving is the *what-if-not* approach, for example, studying how variation of theorem hypotheses alters theorem conclusions. Interestingly, there is a direct 1-1 correspondence between the life-cycle methods of such explorations and the life-cycle methods of writing (Mendez & Taube, 1997). This 1-1 correspondence facilitates combining writing and exploration in the same course.

A second branch of the "creative problem writing" approach seeks to classify general methods of changing a *base* problem (Contreras, 2007; Crespo & Sinclair, 2008). This more modest approach to creative problem writing complements broader problem-writing methods involving exploration, experimentation and what-if-not analysis.

While there is agreement that homework problems should be as challenging as course material itself, nevertheless, several obstacles arise in achieving this goal.

- Lack of training: Although many instructors are aware of the need for a problem solving component in courses, their own understanding of what good problem solving is, and how to create good problems, is often vague and unclear (Stecher & Mitchell, 2007) Consequently, a collection of specific methods to creatively extend base problems is welcome.

- Lack of time: Secondly, even instructors who are gifted in encouraging exploration and creativity, must devote time to *completing the syllabus*. The syllabus typically consists of fixed topics, fixed theorems, fixed formulae or fixed methods which the student must master. It consequently becomes important for every instructor to have a repertoire, or scheme, of methods by which fixed syllabus topics, methods, theorems and formulae can be creatively taught using semi-mechanical methods of problem extension and enrichment.

- Creativity versus skill competencies: Thirdly, time for exploration and creativity is not always available, particularly, in more technical courses, such as advanced calculus, advanced English style, or actuarial courses. These courses typically prepare students for career paths requiring highly complex skill competencies; course time is precious. The methods of this paper are especially useful for such advanced courses since it affords an opportunity for creativity and challenge.

This chapter offers one possible method, TSP, two-step problems, to create challenging problems (Hendel, 2010a, 2013). The method is basically mechanical, easily mastered, and can be implemented without much effort or time; nevertheless, the problems are challenging.

The basic idea of TSP is to ensure that all problems address executive function. This can be accomplished by converting all problems into problems that have at least two components; hence the name, *two step problems.* A variety of sophisticated examples from university mathematics, essay writing, biblical interpretation, and several other subject areas may be found in the original TSP articles (Hendel, 2010a, 2013).

In this paper, illustration of the method is provided using elementary school arithmetic. The basic idea is transparent and can be transferred to other areas. The examples address teaching the addition and multiplication tables, a task which can easily be presented at the rote or memorization cognitive level. In each of the examples below, the problems are raised to a higher cognitive level by creating a TSP, two-step problem, with each problem a simple application of the addition and multiplication tables.

Although, the TSP itself *appears* simple and lower cognitive level, such problems *are challenging*. This contradiction between appearance and reality in a two-step process – *appears simple* but *is challenging* - is fully consistent with the psychological executive-function literature.

> Example: The deceptively simple trail-making test, which requests that an examinee complete a trail starting at 1, and ascending by alternate letters and numbers, for example – 1, A, 2, B, 3, C – the numbers and letters being provided at random on a sheet of paper, *is* considered a good test of executive function and *is* useful in assessing current brain damage and the chances of recovering from a stroke *despite* the *appearance* that counting 1, 2, 3 and enumerating A, B, C *appears* simple (Bowie & Harvey, 2006; Corrigan & Hinkeldey, 1987; Gaudino, Geisler, & Squires, 1995; Reiten, 1958).

Next, examples of TSP from elementary arithmetic are presented.

.

> Example 1 – Parallel TSP: 3 + *some first number* = 7; 4 + *a second number* = 12. Calculate the sum of the first and second number
>
> Example 2 – Sequential TSP: 3 + 4 = *a first number*; 4 + *a first number = a second number*. Identify the first and second number

The answers should be obvious (for Example 1: the first number and second number are 4 and 8 and their sum is 12; for Example 2, the first number is 7 and the second number is 11). Other methods of combination are also

possible. Other formulations of the question – for example, using blank lines, or boxes to be filled in, or even letters – are possible depending on the student level.

As already noted, the application of the TSP method applies to all course levels including the university level, and including diverse areas like essay writing, and advanced mathematics. The resulting problems, although easily produced, without draining needed course time, nor requiring instructor training, are nevertheless challenging and use executive function, an educational pillar.

### 7.5 Efficiency in Student Diagnostics and Advising

As developed in Section 6.6, a major educational pillar is *self-efficacy*, a student's confidence that with their current skills and knowledge they can perform a specific task. The most important driver of *self-efficacy* is *performance*. Modern technology affords us a wonderful opportunity to implement this. The punchy story immediately below illustrates this point.

> At a certain university, the remedial (introductory) algebra course used computer assisted software. Since, the software required a login to a central system, all usage was completely captured. An instructor relates the following incident, a conversation that happened between a failing student and the instructor
> *Instructor*: Although you have failed, this does not reflect any lack of ability on your part, but lack of effort.
>
> *Student*: No. I did all the homework. I don't think these practice problems work.
>
> *Instructor*: I have here time-usage statistics by student. Interestingly, I have average time usage among those achieving A,B,C,D,F. This chart shows that those who practice sufficiently (with there being some variation in time needed) invariably get higher grades, while those students not practicing get lower grades. This is consistent with the lack of time you put in and the resulting grade.
>
> *Student*: But I put in the time.
>
> *Instructor*: The system shows you logged in for only so many hours. Judging by the time you logged in, it appears that you only spent 10-15 minutes a session, since a new TV show was being shown at the time you left.

The story, with some amusing overtones, highlights the importance of performance as a driver for self-efficacy. Also, as noted in Table 4 of Section 6.6, *role-modeling*, seeing how others have mastered a skill, is an important driver of *self-efficacy*. This is accomplished above by the instructor sharing statistics of average time spent practicing by letter grade achieved. Thus, use of the software facilitates two important drivers of self-efficacy, *performance* and *role-modeling*.

There are other educational benefits from using software which can be elegantly formulated using the four educational pillars. In the anecdote just cited, by sharing overall time-usage statistics, this instructor also shares with the student the important point that *effort*, not innate ability, leads to success. Such a perspective is consistent with the educational pillar of *attribution* theory; the data speaks for itself and allows students to graphically see this relationship thereby motivating them.

With the increasing use of software technologies, such practices can become more common. Furthermore, a sophisticated IT system is not needed; if all the software does is store a databank of exercises (with perhaps a crude breakdown of exercise difficulty) and allows logging of all time spent by students, it should suffice to be an effective diagnostic and advising tool.

In concluding this particular example, and generally, in concluding all the examples presented in this Section 7, it is noted that a key tool in all examples is the skillful use of the four educational pillars to facilitate easy recognition, formulation, and use of methods and ideas that raise pedagogy to a cognitively challenging level.

## 8. Conclusion

This chapter has reviewed some current hot areas of educational problems and experimentation with solutions. These areas include skillful integration of education with vocational aptitudes, the infrastructure found to be successful to eliminate disparity gaps in STEM education, and the transformation of coursework and homework to a pedagogically challenging level using the four educational pillars.

The methods presented in this chapter have their source in the practices of countries and government entities around the world as well as in well-established theoretical results in other disciplines. The chapter's main goals were to show that many problems have *already* been solved, to bring these successes to readers attentions, and to collect these results in one place.

The techniques, methods, and ideas presented in this chapter significantly reduce, and sometimes eliminate, a variety of current problems in multiple educational areas such as lack of student motivation, lack of student retention, student delinquency and recidivism; the methods presented also facilitate elimination of gaps, increase instructor research, expand homework problem resources that are at a cognitively challenging level, provide good student diagnostics, as well as provide methods to teach, with success, traditionally difficult areas such as essay writing and mathematical verbal problems.

It is hoped that these examples are sufficient to motivate further application, use, and verification of these techniques to other areas of education.

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