Remediation for Holistic- vs. Analytic-Learning Styles in Technical Courses

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ABSTRACT

This paper uses a convergence of methods from four disciplines to develop a simple technique useful in significantly improving student performance in technical courses. Very roughly, the method consists of a teaching-delivery style using a holistic-analytic sequencing of topics: First, broad intuitions and heuristics are presented without technical details, followed by a technical component which develops details on the foundation of intuitive concepts. This approach can equivalently be formulated as a top-down approach (software design), progression from the recognition to the analysis level (Van Hiele), progression from the remembering to the analyzing Bloom levels, or from a field independent learning style to a field dependent learning style (multi-dimensional learning style theory). Four case studies are presented, involving traditional students, students with severe mental disabilities, and textbooks from computer science and introductory math courses. We provide guidance and references for those wishing to apply the methods of this paper. We also discuss several obstacles to statistical verification of the proposed method including survivor bias and needed length of treatment. The primary purpose of this manuscript is to present the basic ideas, show a broad basis of support in several disciplines and encourage further research and experimentation.

Keywords: Van Hiele, Bloom, Anderson, field independence, top-down, holistic, analytic, education, pedagogy, remediation

1. INTRODUCTION AND GOALS

The purpose of this paper is to show how a conceptual framework common to four disciplines – the Van Hiele (Fuys) approach to Geometry, the Bloom-Anderson taxonomy of educational concepts, the top-down approach of software design, and the learning style dimension of field-(in)dependence in multi-dimensional learning style theory - can be used to achieve significant improvement in student performance in technical courses.

The method is particularly successful on students whose learning style is holistic vs. analytic. The problem with these students is that their holistic approach appears ill-suited in a technical course. Very often an instructor, reviewing initial work – papers, homework, tests, and projects – of such students, forms an opinion that these students are hopeless because of their holistic non-detailed approach which is ill-suited for a technical course. The instructor’s negative opinion very often further steer’s these students towards failure.

This paper suggests an approach to remediation that employs a pedagogical delivery using a holistic-analytic sequencing of topics. The suggested approach accepts the student’s initial holistic approach and proceeds to build on it enabling a mastery of technical concepts.

To support our thesis, that holistic-analytic sequencing is a useful concept in remediation, we perform a meta-analysis of four disciplines which shows a convergence on use of the holistic-analytic sequencing. The four disciplines are:

1. The top-down approach to software design;
2. The Witkin multi-dimensional learning style model;
3. The Van Hiele (Fuys) approach to Geometry; and
4. The Bloom (Anderson) taxonomy of learning concepts.

These four disciplines each exploit the equivalent of a holistic-analytic sequencing of topics in their approach to teaching. This convergence from multiple disciplines strongly supports our suggested method of remediation using a holistic-analytic sequencing approach.

In the final section of the paper we present several case studies illustrating application of this approach. We also reformulate this approach in terms of concept mapping.

An outline of the rest of this paper is as follows. In the next four sections we briefly review from the four disciplines enumerated above those components that use holistic-analytic sequencing. In the final section of the paper we examine four case studies and discuss three obstacles or issues with statistical assessment of this approach.

Other authors have performed comparisons of different learning theories for purposes of ascertaining broad common themes of pedagogy. For example, Pegg [10], who examines and compares SOLO, Brunner, Van Hiele and Piaget, comes to the conclusion that:

“What stands out from such theories is the gradual biological development of the individual, growing from dependence on sensory perception, through physical interaction and on through the use of language and symbols to increasingly sophisticated modes of thought.”

The meta-analysis presented in this paper formulates a different commonality of approach. The common approach presented in this paper uses well-researched, in-classroom, pedagogical concepts and learning styles such as holism and analysis. This allows the interested reader to draw on a rich literature shared by several disciplines and apply these methods in actual classroom settings. Further details will be presented in the closing sections.

2. TOP-DOWN DESIGN

In this section we review the top-down software design
Top-down design is a general method that is universally used in software design and covered in almost all textbooks on the subject. Top-down design refers to a problem-solving approach; it suggests that initially a problem should be solved in broad general terms and only subsequently should technical details be filled in. Top-down design is often contrasted with bottom-up design in which the technical details and code are written first and subsequently the problem is solved at the top level.

To illustrate the top-down approach we take a simple example: Designing a program to shuffle a card deck [3]. We present the analysis in terms of an imaginary dialogue between an instructor (I) and student (S).

I: Write a program that shuffles and deals a card deck.
S: I haven’t the foggiest idea how.
I: You never played cards?
S: Well of course I know what a card deck is …
I: Can you tell me any details about the card deck?
S: Each card has a number, suit and color.
I: How many?
S: There are 52 cards.
I: What about the suits, numbers and colors?
S: There are 4 suits, 13 numbers and 2 colors. Also 11,12 and 13 are written with letters, J, Q, and K.
I: Well your assignment is to shuffle the deck and deal it.
S: I don’t know how to do that
I: Have you ever played cards? What happens when you shuffle a deck?
S: The card order becomes random.
I: Does that remind you of anything we have learned.
S: Yes, there is a random function but I am not sure how to use it here.
I: The card deck, the suits, and the numbers are collections of similar things. How do we deal with collections of similar things.
S: We use an array to represent collections of similar things.
I: Where else would this array-collection concept be useful.
S: Well each dealt hand is a collection of similar things; the card deck is a collection of cards; the suits and numbers are collections of similar things.
I: Why don’t you summarize what we have done till now.
S: We have outlined the following steps but I am still unsure how to proceed
1 Create a list of suits (use Array);
2 Create a list of card numbers;
3 Create a deck of cards with each card having a suit and number;
4 Create a list/Array for each player;
5 Randomize the suits and numbers of the card deck;
6 Transfer (‘deal’) the resulting randomized card deck to the lists associated with each person playing.

The above bulleted list completes the top component of the top-down analysis. The software designer, in a subsequent part of the course, would take each individual bullet and transform it into software code. The result is the completed program that shuffles and deals cards.

Some important characteristics of the above process are the following:
1. It is deliberately non-technical; there is no computer code; there are very few technical terms;
2. It is vague and holistic rather than specific, detailed and analytic;
3. The above dialogue does not seem to make any reasonable progress towards solving the assignment: If, for example, one assesses the closeness to completion of task by the number of lines of correct code written, the above discussion would score 0 (Since indeed, no code has been written). In other words, the above analysis leaves one with a feeling that nothing has been accomplished and that any further progress in the solution would not have needed the initial stage.

Nevertheless, the above top-down analysis is considered, by every professional programmer, as a real initial accomplishment and real progress towards a solution.

From a point of pedagogy we are not borrowing the full top-down method. We are rather borrowing the implied underlying holistic-analytic sequence. In the next three sections we continue the exploration of this holistic-analytic sequence in several other disciplines.

3. MULTI-DIMENSIONAL LEARNING MODELS

In this section we review the Witkin theory of multidimensional learning styles [16]. The studies of Witkin in fact initiated the whole field of multi-dimensional learning styles.

The fundamental assumption of learning-style theory is that the seemingly random variation in learning behavior between different individuals is due to basic differences in the ways these individuals learn. A good history of the development of learning style theory may be found in [11] who presents three classical multidimensional learning style models. For a more recent review of the literature see [15].

The simplest type of multidimensional model is a dichotomous one-dimensional model. Such a one-dimensional model was formulated by Witkin, who originated the study of learning and cognitive styles. The Witkin GEFT (Group Embedded Figure Test) determines a learner's cognitive style by studying how the learner finds simple geometric figures embedded in more complex figures. Witkin devised this test after preliminary results from three experiments: (i) the Body-Adjustment Test, (ii) the Rod-and-Frame Test, and (iii) the Rotating Room Test. Each of these experiments studies cognitive determinations of geometric attributes. For example the Rod-and-Frame test studies how different positions of rod-tilt and body-posture affect the perception of the upright position. These three experiments expose two fundamental approaches to cognitive determinations. This led Witkin to formulate the concept of
A field-dependent cognitive style refers to a way of organizing and processing information in which the field is seen holistically as a single unit. This definition includes a tendency to rely mainly on external references.

By contrast a field-independent cognitive style refers to a way of organizing and processing information in which the objects in one's field of vision are seen as separate units. This definition includes a tendency to rely upon internal references. Field-(in)dependence may be called a dimension of cognitive style, since each subject is classified as being either field-dependent or field-independent. It is important to emphasize that 1 Cognitive style is an attribute of the individual, not of the particular learning situation. Witkin showed consistency among subjects - those say, who were field-dependent in the rotating-room test, also, by and large, tended to be field-dependent in the rod-and frame test. Consistency may be established statistically after the results of several learning situations, to a group of subjects, have been performed. 2 The consistency of a learning-style dimension is important since it establishes stability over time, and it is precisely this stability that allows us to call the dimension an attribute vs. a process.

The study of the consistency of the dimension of field-(in)dependence continues by modem researchers. For example, French found positive relationship between the GEFT and scores on (an adaptation of) Kagan's visual analysis task [4]. Witkin suggested that cognitive style was independent of intelligence. Such independence helps justify the term style. There have been several studies of correlation between intelligence and learning style attributes.

It seems reasonable that the attribute of field-dependence corresponds to a holistic approach while the attribute of field-independence corresponds to an analytic approach. In order to place multi-dimensional learning style in the broader context of this paper, and anticipating the results of our next sections, we point out that the multidimensional learning style literature is negative on its use in remediation. As a simple example, the theory outlined above indicates that when talking about, say, slanted squares, there are two types of learning styles: (a) Those that see the slanted square holistically without explicit awareness of its component parts – for example its four right angles - and (b) those that see the slanted square analytically, for example, as a polygon with four right angles. Since the multidimensional literature considers learning styles consistent and stable over time it does not allow the possibility of change, improvement and progress. By contrast, the Van Hiele and Bloom approaches, presented in the sections below, do allow change, improvement and progress. As the paper progresses we further explore this difference in attitude on change.

4. VAN HIELE

The Van Hiele educational theory was developed in the late 50s by Pierre and Dina Van Hiele who provided descriptive and prescriptive accounts, respectively, of student in-ability to learn geometry [13]. Although the Van Hiele theory was originally developed for, and is still primarily applied to, the teaching of Geometry, Van Hiele himself asserted that his theory applies to all mathematical understanding and presented examples of his methods applied to the learning of functions and other non-geometric notions [12]. The Van Hiele theory makes the following fundamental assumptions about the learning and teaching of geometry[12]:

1. (fixed sequence) all students learn geometry by passing through a sequence of levels and these levels and their order are intrinsic to the learning experience;
2. (adjacency) at each level of thought what was intrinsic in the preceding level becomes extrinsic in the current level;
3. (distinction) each level is characterized by its own language, symbols, and interrelationship of concepts;
4. (separation) students from different levels typically cannot understand each other; and
5. (attainment) the teaching process enabling a student to completely progress from any one level to the next has five (approximately sequential) phases entitled (i) inquiry, (ii) directed orientation, (iii) explanation, (iv) free orientation, and (v) integration.

Since its inception the Van Hiele theory has been used extensively in the Soviet Union and the Netherlands. It has also begun to be used in the United States.

As in any comprehensive widely-used theory the definition and number of levels have received (somewhat) different treatments by different researchers. For example, Fuys [5] did an extensive study and provided his own characterization. His formulation was reviewed by several researchers including Van Hiele himself and underwent some modifications. For purposes of this paper we are however only interested in the first two levels. They are:

1 Recognition: The pupil identifies, names and compares geometric figures on the basis of their appearance as a whole.
2 Analysis: The pupil analyses figures in terms of their properties, establishes the properties of a class of figures empirically, and uses the properties to solve problems.

To clarify the terminology, note that initially, at the recognition level, a student would be able to recognize say a slanted square, but would not be able to articulate why the slanted square was a square. Typical student responses to requests for justification during the recognition level might take the form, "It is a square because it looks like a square." Such a response clearly indicates a holistic conception of squares without any further analytic distinction.

By contrast, at the analysis level a student would be able to recognize that a slanted square is a square because it has four right angles. Such a response clearly indicates an analytic perception of the square as having component parts.

Van Hiele, Software design, and Field (in)dependence

As indicated above, although the Van Hiele theory was originally developed for Geometry, Van Hiele himself saw a wider applicability of his theories to non-Geometric mathematical concepts. We are going one step further; we explicitly assume that the holistic-analytic progression applies to any technical discipline.

In other words, we see Van Hiele’s recognition-analysis progression, the software designer’s top-down approach, and
Witkin’s field-dependence vs. field-independence as three examples of a deep core pedagogical principle. Our choice of terms – holistic-analytic – to describe this commonality may be regarded as a purely linguistic convenience. Our real intent in using the terms holistic-analytic is to convey the commonality of theme in the recognition-analysis progression, top-down software design approach and the field-independence dimension of personality style.

A serious problem in comparing these three theories/approaches is that while the Witkin personality style theory is negative on change, or progress, from holistic to analytic, the Van Hiele theory and the top-down software design approach are positive on the possibility of progress.

To resolve this contradiction of opinion on the possibility of change we would point out that:

- The Witkin theory was initially applied to adults not undergoing any training. The Van Hiele-ists do not disagree; without training, progression between levels cannot take place.
- Even the Van Hiele-ists, who believe that progression can take place between levels, agree that change is slow. For example Dina Van Hiele estimates the need for 20-50 sessions for progression between the lower levels [12].

Using the above two bullet points we can resolve the contradiction between the Witkin vs. the Van Hiele / top-down approaches as follows:

- All three theories / approaches agree on the existence of two types of learning which we have termed analytic and holistic;
- All three theories / approaches agree that these levels are stable and consistent over significant periods of time (for example they cannot be changed in a week or two);
- All three theories agree that without training no progression can take place between levels; and
- Two of the three theories / approaches assert that with proper and adequate training progression can take place between levels.

A further insight on progression between levels can be obtained by comparing Piaget and Van Hiele: Van Hiele is more optimistic than Piaget believing that cognitive development in geometry can be accelerated by instruction [12].

5. BLOOM

Abraham Bloom, inspired by the 1948 Convention of the American Psychological Association, spearheaded a group of educators who eventually undertook the task of classifying educational goals and objectives. Their intent was to develop a method of classification for thinking behaviors that were believed to be important in the processes of learning. In 1956, work on the cognitive domain was completed and a handbook commonly referred to as "Bloom's Taxonomy" was published [2].

The Bloom taxonomy introduces six levels of learning. The levels have received a variety of illustrative examples and characterizations and are regarded as sequential.

During the 1990's, a former student of Bloom's, Lorin Anderson, led a new assembly which met for the purpose of updating the taxonomy, hoping to add relevance for 21st century students and teachers. This time representatives of three groups were present: cognitive psychologists, curriculum theorists and instructional researchers, and testing and assessment specialists. Their work was published in 2001. The Anderson version of the Bloom Taxonomy uses verbs instead of nouns and introduces a 2-dimensional taxonomy model using the dimensions of Knowledge and Cognitive Process [1].

The Bloom Taxonomy has been widely used for several decades in a variety of disciplines and applies to all spheres of learning. Since Bloom's taxonomy applies to all domains of knowledge it will prove useful in supporting our proposed extension of Van Hiele's holistic-analytic distinction to a broader range of knowledge.

Although researchers do not unanimously agree on the definitions of the six levels, for the purposes of this paper it will suffice to use just two Bloom levels:

1. (1) The various charts explain the Bloom remembering level as simply recognizing. This would correspond to a holistic perception.

2. (2) An analytic perception would correspond to the analyzing level. However, in simpler situations it could also correspond to the understanding or applying level:

   - If a student recognizes a slanted square, drawn with wavy lines, as having four right angles, then they have analytically identified the slanted square by its component properties which are non-traditional (wavy vs. straight lines). This corresponds to the analyzing Bloom level.
   - However, if a student recognizes a non-slanted square as a square because it has four right angles then they are only at the understanding level; and similarly,
   - If a student applies the concepts of right angles to the tilted right angles of a slanted square then the student is at the applying level since they are transferring their knowledge of right angles to a new situation.

In any event the holistic and analytic stages that we have studied in this paper correspond to two distinct Bloom levels. As Pegg [10] observed in his own comparative study, we are not, for purposes of this paper, particular about the exact details of each level and each theory but rather are emphasizing a broad commonality. For example, on a deeper level it may indeed be the case that what we have called analysis corresponds to three sublevels – 1) understanding, 2) applying and 3) analyzing. The purpose of this paper is to present the broad idea of two distinct levels – holistic and analytic. The above analysis of Bloom levels supports this.

Summary: Software design, Witkin, Van Hiele, Bloom

In sections 2-5 we have reviewed four theories or approaches to teaching. Although differences exist between these theories/approaches there is also a commonality. We summarize our main findings immediately below and also include principles for application in classroom settings. The common features of the four theories and their application are that:

1. 2 Levels: Learning and learners in technical domains progress through at least two stages, holism and analysis. It is important for technical students to possess both skills;

2. Holism: Holism refers to a tendency to see things holistically without explicit awareness of component parts

3. Analysis: Analysis refers to a capacity to see things...
In the next section we will refer to these six headings – two-course.

In 1987 I taught a routine introductory mathematics course, MCLA – 1987 case study nicely illustrates. Using our summary at the end of the last section we see that this student with little further teaching being done by the instructors. The majority of work was done by the faculty member who was happy to complete the project I had begun. The result was that the student successfully passed the computer course in the C programming language given by the author. His final score was 36. A careful review of the final showed that the student had correctly holistically approached each problem. The student’s final, because of its lack of technical details, gave an appearance of a student who knew nothing about programming without any further hope. This, coupled with his mental disability, would have led most instructors to simply fail the student without further recourse.

The student had approached me, after being advised of his failure, asking what he could do. I designed a makeup course. My idea was to build on the holistic approach of the student and enable him to fill in technical details. I complemented the student on his initial attempts, but explained to him that he had to pay attention to details, for example, such things as matching parenthesis, proper use of commas, semicolons etc. I even made a checklist for the student.

I left Philadelphia shortly thereafter but conferred with another faculty member who was happy to complete the project I had begun. The result was that the student successfully passed the course. This project took a significant amount of time, more than one semester. The majority of work was done by the student with little further teaching being done by the instructors.

Using our summary at the end of the last section we see that this case study nicely illustrates attitude and learning period.

Drexel University – 1998

A student with a mental disability failed an introductory computer course in the C programming language given by the author. His final score was 36. A careful review of the final showed that the student had correctly holistically approached each problem. The student’s final, because of its lack of technical details, gave an appearance of a student who knew nothing about programming without any further hope. This, coupled with his mental disability, would have led most instructors to simply fail the student without further recourse.

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Textbook supplementation - 1996

I have found this take-home problem technique with an emphasis on problem-type-recognition and broad outlines especially useful in technical courses where the course problems are highly similar. In such courses, the initial challenge to the weaker student is recognition of problems and identification of which technique to use [7].
ability to complete problems once told how to begin [7].

**Current Class Practice**
The chief deterrent to successfully implementing a technique like the *take-home outline problem* in a course is what we have called in our summary, *learning-period*, the fact that student transformation typically can take more than one semester.

Consequently, these days, my goals are more modest. While, I still use the *take-home problem* technique, I use it as a diagnostic tool: There tends to be a high correlation coefficient between the score on the individual outline problem and the overall score on the test. This high correlation allows the instructor to use the *take-home problem* diagnostically; it also provides strong evidence to students that time spent in organization is essential to course success.

**Concept Mapping**
We can elegantly reformulate the *take-home problem* technique in terms of *concept-mapping* [6,8 and 9]. Concept mapping is a technique in which students identify course concepts using, say, labeled circles and then identify relationships among course concepts by connecting the circles labeled with those concepts. The *concept maps* of students evolve as the course and learning progresses. Consequently, the *concept map* is a useful diagnostic tool to assess student progress.

The *take-home outline* resembles concept mapping in that key course concepts are presented and their interrelationships are referred. It differs from traditional concept mapping in two important ways: First, in the *take-home problem* the instructor imposes his/her concept map on the students. Thus we might call this *instructor-imposed concept mapping*. Based on the case studies I presented above it appears that *instructor-imposed concept mapping* has some utility.

A second difference between traditional concept-mapping and instructor-imposed-concept-mapping is that traditional concept-mapping allows any relationship between course concepts. However, in our use of concept-mapping the emphasis has been on two levels of concepts: holistic vs. analytic concepts. I believe that this differentiation between types of concepts is not fully explored in the concept-mapping literature.

**Statistical verification**
This paper is primarily a theoretical study. We hope the broad theoretical background and the diverse case studies will encourage other researchers to conduct serious studies to verify the underlying thesis and discover useful modifications. In this subsection we lightly mention three issues which any statistically sound study must deal with:

1. **Learning period**: A typical course semester is 15 weeks / 30-45 sessions. Reasonable estimates of the minimal learning period needed for change from a holistic to an analytic learning style is 20 – 50 weeks. Thus any reasonable statistical study must span several semesters.

2. **Survivor bias**: Survivor bias is a concept from actuarial science. It refers to the fallacy of studying common attributes of successes but not having dropouts in the study. A possible flaw in such a study arises because the dropouts may in fact have all the attributes which the successes have! In our Drexel case study we have shown that our techniques can be successful on students who look like dropouts. However, not all dropouts can succeed. Therefore, extreme care must be taken to carefully define which students will be included in the study.

3. **Cultural differences**: Statistical justification of any pedagogical method should always be broadly based among several cultures. Whitman et al presents such a study for Van Hiele[14].

**REFERENCES**


