Research on Learning Style: Applications in the Physics and Engineering Classrooms

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Abstract—Several approaches to teaching undergraduate physics and engineering students using both the Dunn and Dunn and the Kolb learning style models are discussed. The Dunn and Dunn learning style model is employed with nonmajors enrolled in introductory physics at American University and the Kolb learning style model is employed with freshman engineering students at Purdue University. The basic elements of these two learning style models are compared and contrasted. Teaching approaches that have been successful with these two distinctly different populations of students will be shared. These approaches can easily be adapted for use by educators in other branches of computing as well as science, mathematics, engineering, and technology education.

Index Terms—Classroom assessment, learning styles, learner diversity, teaching techniques.

I. INTRODUCTION

A GROWING body of research on adult learners suggests that increased learning gains can be achieved when instruction is designed with students’ learning styles in mind [1]–[4]. In addition, several practitioners within the domains of physics and engineering education have noted the importance of teaching with learning styles in mind [5]–[9]. Furthermore, attention to learning styles and learner diversity has been shown to increase student motivation to learn. Quite often when student motivation is increased, larger learning gains are achieved.

This paper addresses the critical role that a learning style approach can play in terms of physics and engineering education. An overview of the learning style models used by the authors will be provided. Introductory physics students at American University are given a learning style assessment based on the Dunn and Dunn learning style model at the beginning of each semester. At Purdue University, a special set of tutorial courses for freshmen engineering students have been designed based on the Kolb learning style model.

Two different student populations have been intentionally selected for discussion in this paper: nonscience majors taking introductory physics at American University, and, at-risk freshman engineering students at Purdue University. These distinctly different populations of students allow the sharing of a very important message with other educators. The message is quite simple. A learning style approach can be successfully adapted for use with any population of students.

II. DESCRIPTION OF STUDENT POPULATIONS

A. American University

The introductory course for nonscience majors at American University, Washington, DC, is a one-semester, algebra-based course and is entitled Physics for the Modern World. Topics covered in the course typically include kinematics, Newton’s laws, conservation of momentum and energy, rotational motion, fluid mechanics, waves, and sound. Although traditional in its content, the course is not taught in a “traditional lecture format.” Numerous teaching strategies have been developed which correspond to the accommodation of students’ needs and diverse learning styles [10]. In addition, the course includes both strong conceptual and problem solving components.

Many students who enroll in the introductory course are liberal arts majors. Students enroll to satisfy a portion of the natural science requirement for graduation at American University. Students may choose to satisfy this requirement with a general physics, chemistry, biology, or psychology course. The population of students enrolled is very diverse. For example, the spring 1999 classes included students from 24 states and 25 countries. Nearly 40% of the class was made up of international students.

B. Purdue University

The population of interest at Purdue University involves students enrolled in an optional, Counselor Tutorial (CT) course designed to provide supplemental instruction for academically disadvantaged students. The CT courses involve special one-on-one tutoring sessions that are held with an instructor from the Freshman Engineering Department, as well as once a week with undergraduate tutors. These courses are tailored for the individual who has the minimum understanding of the course material but who has not yet mastered the subject [11].

The particular CT course to be discussed later in this paper is called ENGR191M. This course provides supplemental instruction for students enrolled in MA151, Algebra and Trigonometry. MA151 is an algebra- and trigonometry-based course designed for students with inadequate preparation for calculus. Over 200 students typically enroll in ENGR191M each year.

III. LEARNING STYLE DESCRIBED AND DEFINED

What exactly is a learning style? Several definitions of learning style currently exist. Keefe [12] defined learning
style as being characteristic of the cognitive, affective, and physiological behaviors that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment. Learning style also represents both inherited characteristics and environmental influences. Dunn [13, p. 224] further described learning style as “...the way each learner begins to concentrate, process, and retain new and difficult information”.

Dunn [14] noted that the uniqueness of individual learning styles could be thought of as a fingerprint. Interestingly, Sternburg [15] indicated that an individual’s learning style can be compared to her/his ability and is therefore not etched in stone at birth. Dunn [16] further noted that a person’s style changes over time as a result of maturation. Dunn also contended that strong preferences can change only over a period of many years and that preferences tend to be overcome only by high levels of personal motivation. She further asserted that teachers are not able to identify students’ styles without the use of appropriate instruments.

Assessing a person’s unique style is vital to the teaching/learning process. Dunn also asserted that a match between a student’s style and a teacher’s style may lead to improved student attitudes and higher academic achievement.

Kolb [17, pp. 76–77] has suggested that, “As a result of our hereditary equipment, most people develop learning styles that emphasize some learning abilities over others”. According to Kolb, there are four distinct forms of knowing: divergence (achieved by reliance on apprehension transformed by intention), assimilation (achieved by comprehension transformed by intention), convergence (achieved through extensive transformation of comprehension), and accommodation (achieved through extensive transformation of apprehension). These forms of knowing are described later in this paper. In the sections that follow, the learning style models used by the authors are described.

IV. DESCRIPTION OF THE DUNN AND DUNN LEARNING STYLE MODEL

This section will focus on the learning style model developed by Dunn and Dunn and the associated learning style assessment instrument developed by Price, et al. [18]. Price et al. suggested that productivity style theorizes that each individual has a biological and developmental set of learning characteristics that are unique. They further suggested that improvements in productivity and learning will come when instruction is provided in a manner that capitalizes on an individual’s learning strengths. As a model, productivity style embraces several general principles that they state in the form of philosophical assumptions:

1) Most individuals are capable of learning.
2) The learning conditions in which different individuals learn best vary extensively.
3) Individual learning preferences exist and can be measured reliably.
4) Most students are self-motivated to learn when they have the option of using their learning style preferences and experience success.
5) Most teachers can learn to use individual learning styles as a basis for instruction.
6) When selected teachers are not capable of learning to use individuals’ learning styles as a basis for instruction, students can be taught to teach themselves and, thus, bypass their teachers’ styles.
7) Use of individual learning style strengths as the basis for instruction increases learning and productivity. ([18, pp. 21–22]

The basic tenet of the Dunns’ model is that individual styles must be assessed, and, if a student is to have the best opportunity to learn, instructional techniques must be used that are congruent with each student’s style. Not all theorists agree with this tenet because they feel it is extreme. Other theorists wrestle with the question of whether we should teach to an individual’s strengths or try to help them develop their weaknesses. The best answer may be both. One of the best ways, especially in large classes, to teach to individual student’s strengths is to use a variety of instructional styles and modes of delivery.

The learning style assessment instrument chosen for this study is the Productivity Environmental Preference Survey (PEPS) by Price et al. [18] This instrument was chosen because of its comprehensive nature, and, because of the relative ease of assessing students and interpreting the results. The PEPS was developed from the Dunn and Dunn learning style model and is described in the following section. The Dunn and Dunn learning style model is based on five different categories: 1) environmental; 2) emotional; 3) sociological; 4) physiological; and (5) psychological. These categories provide the basis for the elements displayed in the feedback profile obtained after student responses to the PEPS have been scored.

The Dunn and Dunn learning style model has had widespread use with adult learners; however, its use in engineering and science education has been quite limited. The research conducted by the lead author represents the only published work with the Dunn model that involves non-science students taking introductory college physics classes. This makes the use of the Dunn model in engineering and science education even more interesting to study.

V. THE PRODUCTIVITY ENVIRONMENTAL PREFERENCE SURVEY (PEPS)

The PEPS consists of 100 questions on a Likert scale. This instrument uses a standardized scoring system that includes scores that range from 20 to 80. The scale is further broken down into three categories. These categories are referred to here as low, middle, and high. The low category represents standard scores in the 20–40 range; the middle category scores in the 41–59 range; and the high category scores in the 60–80 range. Individuals who have scores lower than or equal to 40 or higher than or equal to 60 for a particular element find that variable important when they are working. Individuals who have scores in the middle category find that their preferences may depend on many factors such as motivation and interest in the particular topic area being studied.

Looking at one specific example, within the category of environmental stimuli are the elements of sound, light, temperature,
and design (formal versus informal). The elements within this category are self-explanatory. This category is one that is difficult to accommodate in the classroom. However, learners can easily satisfy their preferences when working outside of class. For example, a score $\geq 60$ for the element of sound would mean that an individual has a preference for sound when learning new and difficult information. An individual could accommodate their preference for sound by listening to soft music. A score $\leq 40$ on the sound element would imply that an individual does not show a preference for sound and thus should work in a quiet environment (using earplugs if necessary). A score in the middle category means an individual might prefer sound at one time, and not at another.

Once the PEPS is administered, students should receive an individual feedback profile as quickly as possible. Students must immediately be made aware that no high or low exists on this scale in terms of superiority of scores. Furthermore, no scores are bad scores—all are simply unique. No scientific evidence shows that one type of learning style is academically superior over others.

Numerous research studies [19] have documented the reliability and validity of the PEPS. Dunn and Dunn [20] posited that research on their model is more extensive and more thorough than research on many educational topics. As of 1998, research utilizing their model had been conducted at more than 112 institutions of higher education, at all levels $K$-college, and with students at most levels of academic proficiency, including gifted, average, underachieving, at-risk, dropout, special education, vocational, and industrial art populations.

Dunn et al. [21] performed a meta-analysis of the Dunn and Dunn model of learning style preferences. They reviewed 42 different experimental studies conducted with the model from 1989 to 1990. Their results indicated that overall academic achievement of students whose learning styles have been matched can be expected to be about three-fourths of a standard deviation higher than those of students whose learning styles have not been accommodated.

VI. DESCRIPTION OF THE KOLB LEARNING STYLE MODEL

David Kolb, a cognitive theorist, developed the learning style inventory (LSI) in 1976 [22]. The LSI was a nine-item self-report questionnaire in which four words describing one’s style were rank-ordered. One word in each item was used to correspond to one of four learning modes. Within the Kolb learning style model four learning modes are identified: 1) concrete experience (CE); 2) reflective observation (RO); 3) abstract conceptualization (AC); and 4) active experimentation (AE).

The concrete experience mode describes people who feel more than they think. Individuals in this mode tend to be very good at relating to others and they tend to be intuitive decision-makers. The reflective observation mode describes people who would rather watch and observe others rather than be active participants. Individuals in this mode tend to appreciate exposure to differing points of view. The abstract conceptualization mode describes people who think more than they feel. Such people tend to have a scientific approach to problem solving as opposed to a more artistic approach. Finally, the active experimentation mode describes individuals who take an active role in influencing others as well as situations. These individuals welcome practical applications rather than reflective understanding as well as actively participating rather than observing.

In his work Kolb identified four statistically prevalent learning styles [1]. These styles are referred to as the diverger, the assimilator, the converger, and the accommodator. Felder describes these styles as Type I, Type II, Type III, and Type IV, respectively [23]. Fig. 1 shows that these styles (or types) can be graphed on a coordinated grid illustrating the bipolar dimensions of doing (active experimentation) versus watching (reflective observation) on the $x$-coordinate, and feeling (concrete experience) versus thinking (abstract conceptualization) on the $y$-coordinate.

The diverger’s (Type I) dominant learning abilities are concrete experience and reflective observation. These learners are able to put their creative imagination to good use. Divergers tend to excel in their ability to view concrete situations from a variety of perspectives and to combine relationships into a meaningful whole. Divergers are “people persons” who are imaginative and emotional.

The assimilator’s (Type II) dominant learning abilities are abstract conceptualization and reflective observation. Assimilators are less interested in people and are more interested in abstract concepts. Assimilators are very good at synthesizing disparate observations into an integrated explanation. They work well when information is detailed, logical, and orderly.

The converger’s (Type III) dominant learning abilities are abstract conceptualization and active experimentation. Convergers seem to do best when there is a single correct answer to a problem or question. These individuals tend to be less emotional and do not like to waste time. Convergers would prefer to work with things and not people.

The accommodator’s (Type IV) dominant learning strengths are concrete experience and active experimentation. The Accommodator tends to be a risk-taker. Accommodators are intuitive and tend to do well in situations that call for adaptation to specific immediate circumstances. These individuals tend to work easily with other people, yet can sometimes be viewed as being impatient.

VII. TEACHING AND LEARNING APPROACHES: STRATEGIES UTILIZED AT AMERICAN AND PURDUE UNIVERSITIES

A. American University

All students enrolled in Physics for the Modern World at American University are given the PEPS at the beginning of the semester. Students receive an individualized feedback profile approximately two weeks after that. The profile is similar to a prescription in that it identifies categories (based on the Dunn and Dunn model) in which students have strong preferences and gives them information as to how to best utilize these strengths. Students are also extended an invitation to visit with the instructor individually regarding their learning style profiles.

Teaching approaches utilized in the physics course have been designed, in part, using the Dunn and Dunn learning style model. Two unique teaching approaches will now be briefly...
described. One approach involves a unique writing activity, while the second approach involves the use of a peer-led and instructor-moderated on-line discussion group.

B. Approach (1): The Writing Activity

The first teaching approach to be described is a writing activity. The writing activity was developed to help students elicit and confront their misconceptions in physics in a nonthreatening way. The activity permits direct feedback between the individual students and the instructor. In addition, the activity allows students to be creative and use their unique learning style preferences.

As part of their homework assignments, students are required to keep a two-pocket folder. Students receive 5–10 writing assignments each semester. Upon collection of the folders, a block of time is set aside (approximately 6–8 hours) to read them and provide each student with written feedback. This written feedback is absolutely essential. When students take time to reflect on their writing and on the instructor’s comments, the folder becomes a highly effective tool in helping them uncover and then wrestle with their misconceptions while the learning is taking place. Typical folder activities range in length from 1–4 pages.

The specific emphasis of the writing activities depends on the goals and objectives for a particular topic or content area. For example, for some activities students are asked to explain a problem or a concept that was highlighted or discussed during a class session. Thus, students essentially have the “answer” to the problem in their hands when they write up this folder assignment. The rationale for this type of activity is that learning can be enhanced when students take on the role of teacher through their detailed responses and explanations.

An additional example of a typical folder activity involves the creation of sample exam questions. In addition to writing a question, students must explain their choice of responses (i.e., for multiple choice questions) including the reasoning behind both the correct response as well as the incorrect options.

Students are encouraged to share their understanding of the particular topic or concept in their own words. Thus, students are not pressured to bog their writing down with scientific jargon. This provides a much clearer window into the students’ thoughts and to their level of understanding.

An important aspect of the writing activities is that students are permitted to be as creative as they would like to be. Students are encouraged to write their responses in a fashion that allows them to make use of their individual learning styles. For example, some students like to enhance their writing through the use of manipulatives and artistic drawings. Other students might choose to write their responses in the form of a story or short play. The students know that they have complete control of this activity and are free to put their learning styles to good use!

C. Approach (2): The On-Line Discussion Group

The second teaching approach used with introductory physics students involves the use of an on-line discussion group. The on-line discussion group is a useful way of allowing for peer-given, rather than instructor-given feedback. The on-line discussion group has also proven to help students elicit and confront their misconceptions.

The on-line discussion group used with the introductory physics students is peer-led and instructor-moderated. The most common use of the discussion group by the students is discussion of homework questions. A student may post a specific question to the group, describe their confusion, and ask for assistance. Other members of the class are then free to jump in and offer the student help and advice. If the students fall off course with their discussion, the instructor will offer some guidance and attempt to steer the discussion back on track. Other uses of the discussion group include posting of announcements and general discussion questions by the instructor.

The use of an on-line discussion group offers a relatively new avenue through which the learner can take an active role in the learning process. Furthermore, an on-line discussion group is one form of computer-assisted communication that promotes interactive engagement of the learner with the content being studied. An on-line discussion group learning format may offer some students a more “comfortable” environment in which to interact than the traditional large lecture class. In addition, an on-line discussion group may appeal to students with diverse learning styles.

D. Purdue University

The standard, first-semester mathematics course for engineering students at Purdue University is calculus. However, approximately 20% of the entering students are not calculus-ready and must start in MA151, Algebra and Trigonometry. To assist these students, the Schools of Engineering offer a supplemental instruction Counselor Tutorial (CT) course, ENGR191M, that is designed to help the academically disadvantaged become calculus-ready.

Studies [24]–[26] have shown that if students are successful in MA151, then retention rates for these students do not differ significantly from that of students who are initially better prepared. Students in the ENGR191M course are not treated as remedial students, however. Furthermore, the ENGR191M course is organized in such a way so as to acknowledge learner diversity through the recognition of individual learning styles. To accomplish this, the ENGR191M course was designed around the
Kolb learning style model. Specific examples of applications of this model are given in the discussion that follows.

E. The ENGR191M Course at Purdue: Applications of the Kolb Model

Divers (Type I) are students who perceive information through concrete experience, rely on feeling, need to express feelings when learning, seek personal meaning as they learn, and desire personal interaction with the instructor as well as other students. To be effective with Type I students, the instructor should function as a motivator. Thus, the instructor should develop ways to motivate these students and show them how the course material fits into the big picture.

Type I students also benefit from individual counseling. To accomplish this, the ENGR191M course has a one-on-one counseling component where each student meets once a week with an instructor to discuss both the successes and failures for the past week. During this time, the student is given time to reflect on how this as well as other course work fits into the big picture as it relates to his/her particular area of engineering.

Assimilators (Type II) perceive information through abstract conceptualization and process material through reflective observation. These individuals like information simply for information’s sake, want to know what the experts think, and seek a conceptual understanding of what they are learning. Type II learners do well in traditional school settings. To be most effective with Type II learners, the instructor should function as an expert. Thus, the instructor’s role is one of an authority figure and information giver.

Assimilators like to listen to lectures and prefer that the instructor present course material in an organized and accurate manner. Thus, for these students, the ENGR191M course has a lecture component where an engineering faculty member presents a weekly lecture that summarizes the course material each week.

Convergers (Type III) perceive information through abstract conceptualization and process it actively. These individuals like to test information, to try things, to take things apart, to see how things work, and to learn by doing. Type III learners tend to converge or move quickly to make decisions, to seek one correct answer, and to quickly cut through to the essentials of the matter at hand. To be effective, the instructor should function as a coach, providing guided practice and feedback. Thus, an instructor needs to become less actively involved and allow the students to take a more active role in the learning process.

One of the components of the ENGR191M course involves the requirement that any test taken or assignment prepared by a student in the MA151 course in which a B grade or below is received must be repeated with the assistance of a tutor. This component of the ENGR191M course design allows the individual who is experiencing success to be rewarded with a simple check-in, while simultaneously giving other students valuable one-on-one tutoring without causing embarrassment that might otherwise occur in a traditional classroom setting. Furthermore, this component of the ENGR191M course was actually designed to assist Type I students but it also serves to act as a motivator for Type III students who benefit from personal interaction with the instructor and tutors.

Accommodators (Type IV) perceive information through concrete experience and process it through active experimentation. These individuals enjoy interacting with others through group activities and discussion. Type IV learners are problem solvers and risk takers, typically learning from their mistakes. These individuals can be referred to as accommodators because they take what they have learned and adapt it for their own uses. To be most effective, the instructor should stay out of the way, while simultaneously maximizing the opportunities for students to discover things for themselves. Thus, the instructor’s role tends to be that of an evaluator and motivator.

Type IV learners thrive when the instructor encourages self-discovery. This approach provides these students a needed opportunity to teach themselves while still allowing for some interaction and minimal supervision from the instructor. For this group of learners, the ENGR191M course has a component which permits students to meet in small groups with an undergraduate tutor once a week to demonstrate his/her progress in the MA151 class (homework, quizzes, tests) and to work on special CT problems with the tutors.

In summary, the ENGR191M course has several components that have been designed in accord with the Kolb learning style model. This unique course design offers students with particular learning style characteristics to benefit from a wide range of learning opportunities.

VIII. Conclusion

Acknowledgment of students’ individual learning styles can play a critical role in the learning process. Further, the use of formal learning style assessments can provide useful information that benefits the student as well as the instructor. The authors believe that the learning style assessment tool used is not as critical as the actual assessment of learning styles. Through the specific teaching and learning strategies that have been described in this paper, the authors have demonstrated the value and importance of adopting a learning style approach in the classroom. In addition, they have provided evidence of the value of a learning style approach with two distinctly different populations of students. They believe that the attention given both populations of students in terms of individual learner diversity and learning styles is critical to the success of these teaching and learning strategies.

As part of our ongoing research the authors are working to formally link the assessment of student learning styles to learning gains. Through our continued studies they plan to further ascertain the effectiveness of a learning style approach in and out of the classroom in terms of its impact on student learning within the domains of physics and engineering education.

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