JRTE, *40*(2), 217–245

Accommodating Individual Differences in the Design of Online Learning Environments: A Comparative Study

Mahnaz Moallem
University of North Carolina, Wilmington

Abstract

The purpose of this paper is to report the results of a comparative and descriptive study that examined the relationship and effects of incorporating students' learning styles in the design of instruction and the outcome of students' learning, including their attitude and satisfaction. The paper will first explain how the literature on learning styles was used to develop a list of assumptions about learning styles, and further how these assumptions were used to identify a learning style model. It will also provide a detailed description of the process of using the learning style model to design and develop multiple instructional materials for two units of instruction for an online course. Finally, the paper will report the effects of this approach on students' learning and their perception, attitude and satisfaction in comparison with instructional materials that are designed and developed on the basis of the content and objectives, without incorporating students' different learning styles. (Keywords: learning styles and online learning, instructional design and development, distance education.)

Experienced educators have long supported the notion that individual differences play an important role in learning and instruction. They agree that learners filter instruction through a set of individual lenses (Jonassen & Grabowski, 1993) and tend to manipulate perceived information in different ways, achieve understanding at different rates and in various learning contexts (Barbe & Milone, 1981; Corno & Snow, 1986; Felder, 1993; Felder & Silverman, 1988; Pask, 1988). Experimental studies have also confirmed educators' beliefs by showing how students' styles of learning and thinking make a difference in their academic achievement (e.g., Kim & Michael, 1995; Saracho, 1993; Zhang, 2002). This research suggests that learners whose learning styles match with the given teaching or instructional style tend to retain information longer, apply it more effectively, and retain more positive attitudes toward the subject of the course than those who experienced clashes in teaching/learning styles (e.g., Dunn, 1995, 1999; Felder, 1993; Felder, Felder, & Dietz, 2002; Lovelace, 2005; Riding & Grimly, 1999). However, not everyone agrees with matching learning styles and teaching styles (e.g., Jonassen, 1988; Rector & Henderson, 1970). Rector and Henderson (1970) have determined through their research that the effect of various teaching strategies depends on such factors as the nature of the concept to be taught, the students' characteristics, and the time available. In their study, no significant difference was found in different teaching strategies and student achievement.

The concept of individual differences presents a profound challenge for instructional designers and educators, as research seems to suggest that the quality of learning material is enhanced if the material is designed to take into account learners' individual learning styles (e.g., De Vita, 2001; Rasmussen, 1998; Riding & Grimley, 1999). When designing instruction for a universal audience and for an environment that can be dominated easily by text-based communication and heavy reliance on independent learning skills (e.g., in online or Web-based courses), the designer's/teacher's challenge is to produce a course or instructional material that does not have an obvious tilt toward one learning and thinking style and is diversified enough to meet multiple learning styles. Thus, it is imperative that teachers/instructional designers consult research on learning styles as they devise their adaptive learning materials (Jonassen & Wang, 1993; McLoughlin, 1999; Rowntree, 1992). However, even though current research literature in the area of learning styles and strategies provides teachers/instructional designers with insights into individual differences in learning and performance that can be factored into the design process, little research has focused on the relationship between instructional design of learning materials and learning styles.

The purpose of this study was to examine (i) how and in what ways students' learning styles can be incorporated in the design of instruction, and (ii) what the effects of such an approach have on students' learning and their attitude and satisfaction. The study attempted to answer the following questions: 1) Given the controversial literature on learning styles, can one establish a list of assumptions about learning styles? 2) Which learning style model can be used to design instruction? 3) What are some instructional design specifications for integrating students' learning styles that can guide design and development of instruction in an online learning environment?, and (4) What are the effects of these design specifications on students' learning, their perception, attitude and satisfaction in comparison with instruction that is designed and developed using content and objectives and without incorporating student different learning styles?

LEARNING STYLES RESEARCH: ESTABLISHING A LIST OF ASSUMPTIONS

Review of research on learning style theory does not point to a list of conclusive results. For instance, while some studies show that there may be qualitative changes in the learning style of an individual over time (e.g., Cornett, 1983; Pinto, Geiger, & Boyle, 1994; Price, 1980), others suggest that one's learning style is stable (e.g., Claxton & Ralston, 1978; Cornett, 1983; Kolb, 1976). Moreover, for each research study supporting the principle of matching instructional style and learning style (e.g., Claxton & Murrell, 1987; Canino & Cicchelli, 1988; Ford & Chen, 2001; Hudak, 1985; Lovelace, 2005; Schmeck, 1988; Watkin, 1978), there seems to be a study rejecting the matching hypothesis (Dunn, Beaudry, & Klavas, 1989; Honey & Mumford, 1982, 1986; Kolb, 1985). Hence, it seems that there still remains much discussion about the nature of the construct of learning style, and whether it is more effective to match or mismatch learning style with instructional style. Despite the above controversies in the literature and a variety of learning style approaches, we may develop a list of assumptions underlying the concept of learning styles on the basis of existing evidence. These assumptions that are less debatable can then be used as guidelines for designing adaptive, flexible instruction.

- Learners exhibit different approaches to acquisition of knowledge (e.g., Kagan, 1976; Grigorenko & Sternberg, 1995; Sternberg, 1998; Watkin, 1978; Zhang, 1999, Zhang & Sternberg, 1998).
- Learning style may be assessed using a questionnaire or psychometric test (e.g., Biggs, 1992; Gregorc, 1985; Myers, 1980; Myers & McCaulley, 1988; Sternberg, 1997) even though the test may be, primarily, a measure of time required to learn (Berliner, 1979; Carroll, 1989).
- Alternative theories of styles use a common root word ("style") and cover roughly similar attributes, but with a different label (Sternberg, 1998).
- Learners may alter their learning styles, depending on the task (e.g., Biggs, 1979; Entwistle, 1981; Sternberg, 1998; Sternberg & Grigorenko, 1995).
- By relating research on learning styles to the design of the learning environment, it is possible to study how learners approach their learning (Biggs, 1987; Entwistle & Ramsden, 1983).
- It is possible and desirable to adapt the instruction to accommodate differences in styles or preferences (e.g., Canino & Cicchelli, 1988; Hudak & Anderson, 1984; Lovelace, 2005; Witkin, Moore, Goodenough, & Cox, 1977).

Selecting a Learning Style Model: Felder-Silverman Dimensions of Learning Styles

A number of learning style models have been proposed over the last three decades (e.g., Hill's Cognitive Style Mapping, 1976; Kolb's Learning Styles, 1984; Dunn & Dunn Learning Styles, 1978; Grasha-Reichmann Learning Style Scales, 1996 (Grasha, 1996); Gregorc, Learning Styles, 1985; Hermann Brain Dominance Models, 1996; Felder-Silverman, Learning Model, 1988; Howard Gardener's Multiple Intelligence Theory, 1983), and each has been used in constructing courses in classes ranging from K to 16. Given the above-mentioned list of assumptions derived from the literature, the Felder-Silverman Dimensions of Learning Style model (1988) seems to be the most appropriate model for learning styles. Felder and Silverman developed their learning style model based on a composite of several theories (e.g., Jung's theory of psychological types, information processing). The model combines several dimensions presented in the Myers-Briggs model (Sensing/Intuitive) with Kolb's information processing dimension (Active/Reflective). It also avoids the complexity of the Dunn and Dunn model. The core idea of Felder and Silverman model is that we, as instructors, should not teach each student exclusively according to his or her preferences, but rather to strive for a balance of instructional methods. Moreover, the teaching style with which students feel most comfortable may not correspond to the style that enables them to learn most effectively (Felder & Henriques, 1995). Felder and Silverman (1988) classify students' learning styles according to five questions (see Table 1, p. 220).

Given these five questions, Felder-Silverman (1988), and later Soloman and Felder (2002), developed the Index of Learning Style (ILS). The ILS is a 44

Table 1: Students' Learning Styles According to Five Questions Asked by Felder-Silverman (1988)

Questions	Student Learning
• What type of information does the student preferentially perceive?	• Sensing learners—concrete, practical, oriented toward facts and procedures • Intuitive learners—conceptual, innovative, oriented toward theories and meanings
• Through what sensory modality is sensory information most effectively perceived?	• Visual learners—prefer visual representations of presented material—pictures, diagrams, flow charts • Verbal learners—prefer written and spoken explanations
• With which organization of information is the student most comfortable?	• Inductive learners—prefer presentations that proceed from the specific to the general • Deductive learners—prefer presentations that go from the general to the specific
• How does the student prefer to process information?	• Active learners—learn by trying things out, working with others • Reflective learners—learn by thinking things through, working alone
• How does the student progress toward understanding?	• Sequential learners—linear, orderly, learn in small incremental steps • Global learners—holistic, system thinkers, learn in large leaps

question, self-scoring instrument, which assesses preferences on four dimensions of learning (the fifth dimension, inductive/deductive was removed from the index later) (active/reflective, sensing/intuitive, visual/verbal, sequential/global).

A Conceptual Framework for Integrating Learning Style Model into the Design and Development of Instruction

The Felder and Soloman's Index of learning style model was used to identify specifications for integrating learning style theory into the design of the instructional materials. Given the model, three main characteristics were defined for developing instructional materials that are tailored to students' multiple learning styles (see Figure 1). First, instructional materials should increase self-awareness and meta-cognition (Apter, 2001; Sadler-Smith, 2001). Knowledge of learning styles can be used to increase the self-awareness of students about their strengths and weaknesses as learners. Research on learning styles and achievement has shown that teaching students how to learn and how to monitor and manage their own learning styles is crucial to their academic success (Atkinson, 1998; Biggs & Moore, 1993; Matthews, 1991). Second, the materials should balance learning tasks and activities so that they would accommodate all learners by taking into account four dimensions of the model (Baldwin, & Sabry, 2003; McLoughlin, 1999). Third, while students should be able to choose to

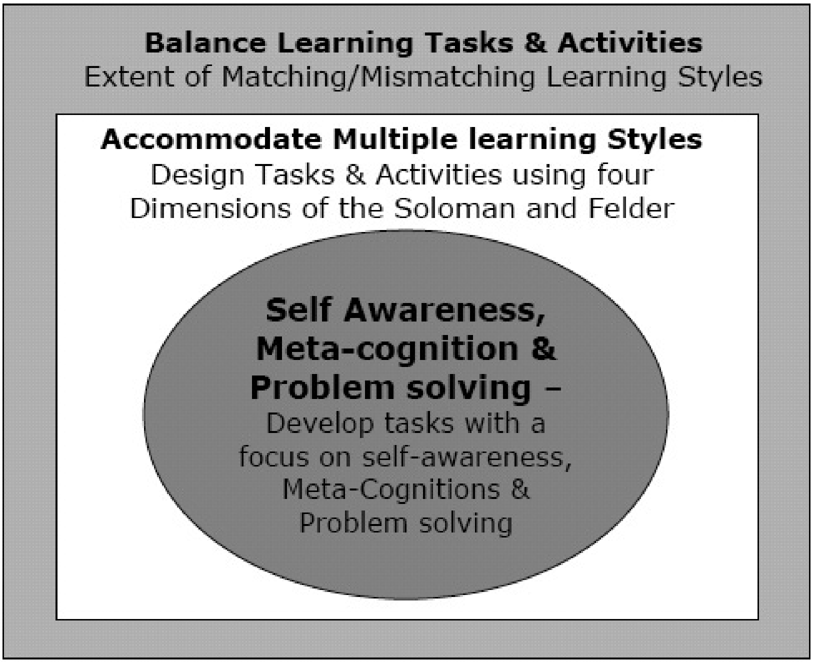

Figure 1: The balanced model for designing instructional materials

learn in a manner they prefer, they should also be challenged to learn in a less preferred manner (Felder & Soloman, 1998), which would provide practice and feedback in ways of thinking and solving problems with which they may not initially be comfortable.

Given the above general framework, a list of flexible and adaptive design specifications (content, curriculum sequence, presentation, navigation/selection, meta-cognitive approach) was identified. According to these specifications, the instructional materials and strategies are complementary, designed to accommodate all learners by providing multiple instructional opportunities (see Table 2), while allowing learners to traverse the course materials according to their learning styles. The specifications listed in Table 2 (p. 222–223) were then used to design instructional materials for two units of instruction that were catered to learning needs of individuals.

In order to determine the proper organization for the multiple instructional opportunities in the design of the materials for each unit, Kolb's theory of experiential learning (Kolb, 1984) was used as a framework. The core of the Kolb's theory is that learners progress through a four stage learning cycle in which *concrete experience* leads to *observation and reflection*, which then leads to *abstract concept* formation (Kolb, Boyatzis, & Mainemeli, 2000). The development of concepts, in turn, leads to new *experiences and further experimentation*, in cyclic fashion. It is argued that the learning cycle can begin at any one of the four points—and that it should be approached as a continuous spiral. Thus, effective learners tend to proceed through all four stages, but they continually choose

Table 2: A Guideline for Developing Instructional Materials Considering Different Learning styles

Questions	Student Learning	Type of flexibility & adaptivity	Instructional Strategies (accommodating differences)
What type of information does the student preferentially perceive?	• Sensing learners—concrete, practical, oriented toward facts and procedures	• Flexible and adaptive Content • Flexible and adaptive curriculum sequence	• Provide concrete and real world examples for new concepts and principles presented in the unit. • Demonstrate procedures by using examples. • Provide real-world learning tasks/activities that allow learners to have concrete learning experiences.
	• Intuitive learners—conceptual, innovative, oriented toward theories and meanings		• Incorporate enough flexibility in assignments and tasks to allow creativity for the concepts learned in each unit. • Provide extra resources and conceptual materials through the use of textual reading materials, summaries and conceptual diagrams to be explored in addition to required readings for each unit.
Through what sensory modality is sensory information most effectively perceived?	• Visual learners—prefer visual representations of presented material—pictures, diagrams, flow charts	• Flexible and adaptive presentation • Flexible and adaptive navigation/ selection	• Provide content related notes in form of charts, matrices, images, and maps for each unit.
	• Verbal learners—prefer written and spoken explanations		• Provide elaborated written and/or auditory notes and explanations with examples. • Offer interactive real time presentation and discussion using synchronous communication tools.

How does the student prefer to process information?	• Active learners—learn by trying things out, working with others	• Flexible and adaptive meta-cognitive approach and problem solving support	• Provide real-world, problem solving tasks and a team environment in order to help active learners engage in critical analysis of issues while working with others. • Provide guidelines for effective teamwork and team self-assessment to promote collaboration. • Provide opportunity for large group discussion using both synchronous and asynchronous communication tools.
	• Reflective learners—learn by thinking things through, working alone		• Provide learners individual tasks/problems to allow each learner to analyze the unit concepts individually and by thinking and working alone. • Provide self-assessment quizzes to make it possible for reflective learners to self-evaluate their own understanding.
How does the student progress toward understanding?	• Sequential learners—linear, orderly, learn in small incremental steps	• Flexible and adaptive meta-cognitive approach and problem solving support	• Provide a detailed and step-by-step procedure for completing each task/assignment both in text and in visual form (tables/charts/images). • Provide specific feedback for each step.
	• Global learners—holistic, system thinkers, learn in large leaps		• Provide conceptual sequence for lessons and completion of assignments/tasks (provide larger leaps and holistic view). • Develop an advanced organizer showing the overall structure of the content and tasks for each unit. • Provide an overview of the material and assignment in each unit. • Provide holistic feedback for each step.

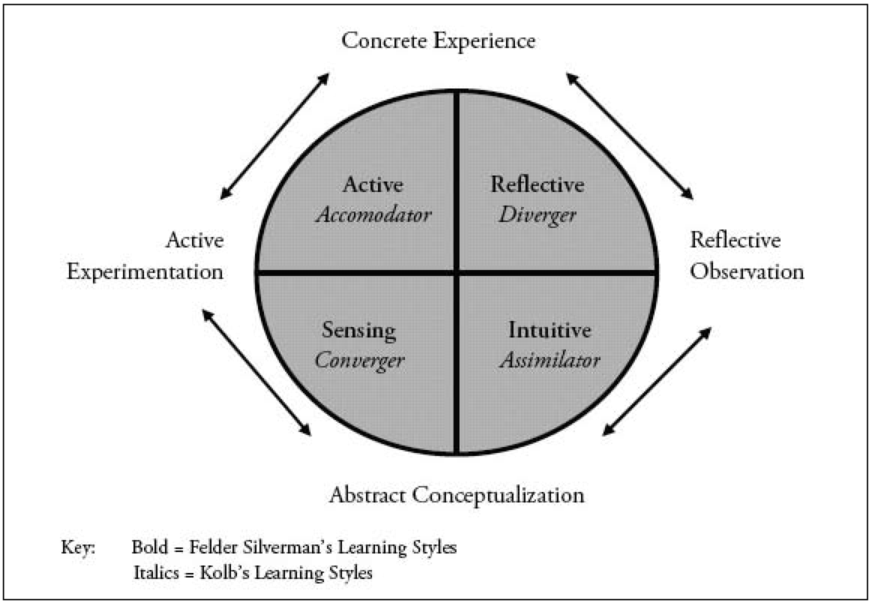

Figure 2: Experiential learning cycle and basic learning styles (Kolb, 1984)

which set of learning abilities they will use in a specific learning situation (see Figure 2). Kolb and Fry (1975) argue that the learning cycle can begin at any one of the four points—and that it should be approached as a continuous spiral. For example, in grasping experience some learners perceive new information through experiencing the concrete, tangible, felt qualities of the world, relying on their senses and immersing themselves in concrete reality. Others tend to perceive, grasp, or take hold of new information through symbolic representation or abstract conceptualization—thinking about, analyzing, or systematically planning, rather than using sensation as a guide. Similarly, in transforming or processing experience, some learners are careful and tend to carefully watch others who are involved in the experience and reflect on what happens, while others choose to jump right in and start doing things. The watchers favor reflective observation, while the doers favor active experimentation. Thus, while learners may choose to proceed with learning the content differently, instructional materials should provide opportunity for learners to experience all four stages.

Using the Kolb theory as a framework, the unit contents and instructional materials were organized into four different levels that correspond to the four stages of learner process. Applying the four stages of the learning cycle led to organizing multiple instructional activities (collaborative real-world activity, reflective individual task, large and small group discussion, self-assessment instrument) in a way to enable students to experience all four stages, while choosing to proceed with their own preferred style. In other words, active learners were able to build on the concrete experience by engaging in a collaborative real-world learning activity (preferred learning style) before reflecting on present and prior learning through a reflective individual task (less preferred learning style). As a result of engaging in a real-world task, active learners were able to form abstract concepts from experience (self-assessment instrument) and apply recently learned content to new tasks and situations by completing a product. The idea was to organize multiple learning materials in a way that learners have an opportunity to choose to learn in a manner they prefer while they are also challenged to learn in a less preferred manner. Kolb's learning cycle assured achievement of the unit learning outcomes, while incorporating multiple learning styles.

Multiple instructional materials were grouped by unit content and outcome goals. The content of each unit consisted of: 1) unit overview, 2) learning objectives, 3) required and optional reading materials, 4) lecture notes in multiple format, 5) collaborative learning activity with an expected product, 6) reflective individual journal, 7) large and small group asynchronous discussion, 8) real time/synchronous discussion and demonstration, and 9) self-assessment instrument/quiz. Collaborative learning activities were designed with a strong focus on meta-cognition and problem solving. The collaborative learning activity confronted students with a real-world situation and context that was problematic and in need of development of a solution or a product. Through inquiry into how peers might approach tasks and by comparing peers' view(s) with their own, students reflected on aspects of the situation that required change. Reflection and self-evaluation then led to team discussion and consensus on a specific plan of action, which in turn resulted in creating the team product. A reflective, individual assignment was also provided in which students were encouraged to reflect on their observations. Self-assessment instruments offered students the option of managing and controlling their own learning and making abstract conceptualizations.

METHODOLOGY

The study aimed to explore the effects of incorporating students' learning styles in the design of instruction on student learning, expectations, attitude, and satisfaction. The exploratory nature of the study suggested a qualitative methodology, although quantitative data were collected and analyzed in order to explore possible effects of incorporating students' learning styles in the design of instruction, in general, and instructional materials and strategies, in particular. As such, rather than just obtaining statistically significant results a comparative design was used as a basis for further exploration (Yin, 1994).

The Course and Its Participants

The proposed conceptual framework used was to design and develop instructional materials and strategies for two units of instruction for a three unit graduate level online course in the area of instructional design theories and research in a southeastern university. The course is a foundation course required of all students enrolled in the Instructional Technology program. The majority of students take the course at the start of their program of study. WebCT Vista was used to deliver the course and its instructional materials. Horizon Wimba was used as a Synchronous Learning Management System (SLMS) for conducting real time discussion and presentations.

The participants consisted of 14 graduate students (ten female and four male), all enrolled in an instructional technology master's program. The researcher was also the instructor of record for the course. Students were assured of anonymity and were informed of their ability to choose not to participate at any time. Thus, none of the students was mandated to participate and all students agreed to participate in the project. Students' ages ranged from 26 to 60 years old. They represented a heterogeneous group of students with regard to age, background, and experience. All students participated in instruction of two units (each unit was one-week long) that were designed, and developed and taught using goals and objectives—a traditional design approach that does not consider students' learning styles. The same group of students then participated in instruction of two other units of instruction that were designed, developed, and taught using the learning styles model described earlier (experimental design). The content and complexity of the units for both approaches were essentially comparable.

Instrumentation

Several instruments were used during this investigation. An autobiographical narrative provided demographic and background knowledge about students. Felder and Soloman's index of learning styles instrument was used to assess students' learning styles. A survey was also used to assess students' perception of the course materials and instructional strategies utilized to deliver the instruction and their attitude and satisfaction. Students' knowledge and understanding of the materials (units' learning outcomes) were assessed through the analysis of the products developed during each unit (students' reflective journals/blogs and collaborative team products) and students' postings in the discussion forum. Students' use of instructional materials was measured by the number of times each instructional material was visited.

Procedures

Students were asked to complete an autobiography at the beginning of the semester explaining their background and experiences along with their expectations for the course and their future goals and plans. The first unit introduced students to the course content and its objectives; it provided them with an opportunity to get to know one another and the instructor, and to establish a work routine for the course. In addition, the first unit introduced students to the content of the second unit through reading materials and initial discussion. Using a traditional design approach, the second unit built upon the content introduced in the first unit. Unit content and objectives were used to identify the best instructional strategies, which was used further to develop the instructional materials and strategies. Given the units' objectives, it was decided that a constructivist approach was a better design for the first two units. Thus, a problem-based collaborative team activity along with student driven synchronous (live conference) and asynchronous discussions (forum) focused on a diverse set of readings were used as instructional strategies for the first two units. At the outset of the units, students were asked to read the required materials and participate in synchronous and asynchronous discussions with the instructor and peers. They were also to begin working collaboratively with their team members to complete a problem-based team activity and submit their products. In order to form teams a sign up sheet was posted and students formed their own teams by choice. The instructor's participation in the large group forum discussion (asynchronous) included posting opening remarks, asking questions if needed, offering more reading resources and finally summarizing the discussion at the conclusion of each unit. The instructor's role during real time discussion was opening the session and facilitating students' discussions and presentations and concluding the discussion by summarizing points made. At the end of the second unit, students completed a survey that assessed their perception and attitude.

Prior to any exposure to the content of the experimental units, students were asked to complete Felder and Soloman's (1998) Index of Learning Styles Survey (a self-scored survey) and report their results to the instructor. Students' learning styles were then summarized and posted for their review. In addition, students were directed to review sites that provided information about different learning and thinking styles and to participate in a real time discussion about learning styles and how they might influence students' learning. Students were also advised to write a reflection in their personal blogs about their own learning style and its educational value. Upon completion of the learning style survey, the instructor exposed students to readings and multiple instructional materials related to units' content. The multiple instructional materials were designed to address students' various learning styles using design framework described earlier (see Table 2). These materials consisted of instructional activities, such as collaborative problem solving tasks, individual reflective blogs, asynchronous discussion board, and the schedule for synchronous discussions. Moreover, rather than facilitating student discussion during synchronous communication sessions, the real time sessions for the experimental design units were divided between instructor's presentation and explanation of the material and student discussion, questions, and reflections. For the presentation part, the instructor used an interactive style, supplemented with multiple forms of presentations (visuals, verbal, polling items, demonstration). As with the traditional design units, at the end of the fourth unit (experimental units), students completed a survey that assessed their perception and attitude toward the instructional materials and strategies.

At the conclusion of the first two units with the traditional design approach, students produced a team product and participated in the large group discussion (asynchronous and synchronous) for each unit. Students' learning products for the third and fourth units (experimental units) consisted of team products, individual reflective blogs, and postings in discussion forum. Students' postings (minimum of four postings for each unit) in the large group asynchronous discussion board, and their team products and reflective blogs were scored by the instructor using evaluation rubrics. The scoring rubric evaluated team products in terms of explicit evidence of using underlying concepts in the proposed solutions or design product, the quality of communicating the results, and the degree of creativity in applying the concepts in practice. The scoring rubric for the discussion forum evaluated student postings in terms of using concepts from the assigned readings, contribution to the group discussion, and clear connection to student previous experiences or ideas presented in previous postings. The general assessment criteria that were used to develop the rubrics were described to students as part of the course syllabus and directions for the course assignments and their expectations. However, for both traditional and experimental units, students were informed that their performance products for the team activities and forum discussions were not numerically graded or counted directly in their final grades; rather, they were counted as part of the student active participation grade in the course. However, students received instructor's detailed feedback and comments for team products and reflective blogs. This strategy was used to ease student anxiety for grades and improve their motivation for learning.

Analysis, Results and Discussion

Both qualitative and quantitative methods were used to analyze data. Analysis of means and standard deviations, a test of correlation and cross tabulation were used to analyze perception or attitude survey and tracking data. Holistic judgment was used to score students' blogs, postings in discussion boards and team products using separate scoring rubrics (Wiggins & McTighe, 2005). Students' scores for each learning product were tabulated and analyzed using descriptive statistics. Paired-Sample T-test was used to compare students' learning for traditional and experimental design units across different measures.

Analysis of student autobiographies showed that 43% of students had from two to 10 years of teaching experiences, while 50% had four to 10 years of work experience in the areas of health education (14%), sales and management in business and industry (21%), and computer and media training (21%). One student had no previous work experience. The results of student learning styles survey are summarized in Table 3. As Table 3 shows, the majority of students were equally divided in different categories of learning styles with visual learners showing the highest frequency. Further analysis showed that all active learners (100%) were also visual learners, while only 50% of reflective learners were visual. In addition, reflective and active learners were equally divided between sequential and global learning styles, while 80% of active learners were intuitive, compared with 80% of reflective learners who were sensing learners. The results of student learning styles were also analyzed to determine whether there was any relationship between students' work experiences and their preferred learning styles, as a number of researchers suspected (e.g., Kolb, Boyatzis & Mainemelis, 2000; Cuthbert, 2005). No correlation was found between categories of learning styles and students' number and type of previous work experiences. This result could be due to the small sample size (14 students) and majority female participants (Ford & Chen, 2001). However, a closer inspection of the data showed that students with teaching experiences tended to score balanced in the areas of reflective versus active and sensing versus intuitive.

Comparative analysis of student perception and attitude survey data for experimental and traditional design units suggested some interesting results. One

Table 3: Results of Student Learning Styles Survey

Learning Styles	% (#/14)	Learning Styles	% (#/14)	Learning Styles	% (#/14)	Learning Styles	% (#/14)
Reflective	36 (5)	**Intuitive**	43 (6)	**Visual**	64 (9)	**Sequential**	50 (7)
Active	43 (6)	**Sensing**	50 (7)	**Verbal**	29 (4)	**Global**	50 (7)
Balanced	21 (3)	**Balanced**	7 (1)	**Balanced**	7 (1)	**Balanced**	0

N = 14

Table 4: Descriptive Results for Selection of Different Types of Interaction

Survey Item	Traditional Design M (SD)	Experimental Design M (SD)
Contributions of interaction between student and content to student learning	3.69 (.48)	3.55 (.52)
Contributions of interaction between the instructor and students to student learning	3.85 (.38)	3.62 (.51)
Contributions of interaction among students to student learning	3.77 (.44)	3.08 (.76)

N = 13 (One student did not complete all surveys)

of the survey items asked students to rate the following three types of interactions used in the course units (Moore, 1989) for their contributions to student learning: (a) student-content interaction, (b) student-instructor interaction, and (c) student-student interaction. Student-content interaction referred to students interacting with the course subject matter through readings or other instructional materials available for each unit. Student-instructor interaction focused on any dialogue between students and instructor (e.g., mail, synchronous and asynchronous communications, or other cognitive guidance and feedback). Student-student interactions referred to interaction among individual students or among students working in small or large groups. When asked to rate contributions (four for very contributing, three for contributing, two for somewhat contributing and one for not contributing) of the three types of interactions to student learning, the mean scores for all three types of interactions were above 3.0 for both traditional and experimental units. However, students consistently rated all three areas of interactions lower for the experimental design units (see Table 4).

In order to further explore the relationship between students' high ratings for the three types of interactions and their learning styles, the frequency of high ratings ("very contributing" and "contributing") for the three types of interactions was calculated for the different types of learning styles (see Table 5, p. 230). The results indicated that students across all types of learning styles rated all three types of interactions lower for the experimental design, with student-

Table 5: Percentage of Students with Different Learning Styles Who Rated Three Types of Interaction as "Very Contributing"

Learning Style	Interaction Content-student		Interaction Instructor-Students		Interaction Student-Student	
	Tradition Design %	Experimental Design %	Tradition Design %	Experimental Design %	Tradition Design %	Experimental Design %
Reflective	83	60	80	66	50	**16**
Active	60	40	83	75	80	40
Intuitive	50	33	83	50	83	**16**
Sensing	83	66	83	66	66	50
Visual	50	44	87	55	87.5	**11**
Verbal	100	75	87	75	50	75
Sequential	67	33	83	50	83	**17**
Global	71	71	86	71	71	43

student interaction being the lowest. One explanation for this result is that when students did not have options, other than participating in a team activity and discussion (student-student and student-instructor interaction), they tended to consider the interaction as a more or major contributing factor to their understanding. However, when students had a choice of selecting among different types of instructional materials and strategies (student-content interaction), some students (except for verbal learners) tended to change their minds. For example, reflective learners who had an opportunity to work individually and with learning materials no longer thought interaction among students contributed as highly to their learning. Similarly, visual learners who had access to visual instructional materials in addition to readings, as well as individual and team activities in experimental design units, did not find the interaction among students as a highly contributing factor to their learning. The lower rating for all three types of interactions for experimental design units may also be due to the novelty of the online course for the majority of students, and their assumption that they would have to work independently in an internet-based course. It is very likely that the novelty of having the opportunity to use different forms of interactions in an online course has worn off after the first two units of instruction (traditional design) in which interaction, particularly among students and between student(s) and the instructor, was the core learning strategy and somewhat novel, given student perception of online courses. In addition, it is also possible that using Horizon Wimba—synchronous learning management tool—as a new technology for real time interaction with the instructor and other students, contributed to students' high ratings for all three types of interactions during traditional design units. However, the novelty of the technology showed to be weakening after using it for two weeks during the traditional design units.

Table 6: Students' Selection of the Instructional Strategies Contributed to Their Learning

Learning Style	Collaborative Team Activities	
	Tradition Design	Experimental Design
Active	80	40
Reflective	50	16
Intuitive	67	33
Sensing	67	0
Visual	75	11
Verbal	50	50
Sequential	67	14
Global	71	29

N = 13 (One student did not complete all surveys)

Another survey item asked students to select from a list of instructional strategies; those strategies that were most contributing to student learning (e.g., team activity, synchronous/real time discussion, readings, online discussion, individual assignments, etc.). Collaborative team activity, readings, and online synchronous and asynchronous discussions were the only instructional strategies available in traditional design units, while individual reflective blog and self-assessment assignments and interactions with multiple instructional materials were added to the list of strategies for the experimental design units. Moreover, as indicated earlier, the role of the instructor and the nature of discussion during synchronous communication changed for the experimental design units. The results of the analysis for this survey item showed that 69% of students across all types of learning styles tended to select collaborative team activity as their first choice, followed by readings (46%) and forum or asynchronous discussion (23%) for traditional design units. For experimental design units, 31% of students across all types of learning styles listed instructor's multiple instructional materials and real time/synchronous discussion (31%), followed by collaborative team activity (23%) and readings (15%) as their first choices. As expected, students tended to differ more in their selection of preferred instructional strategies for experimental units since they had more options available to them. Table 6 compares students' selections of collaborative team activity as their first choice across different types of learning styles.

As Table 6 shows, more students across all types of learning styles tended to select collaborative team activity as their first choice for preferred instructional strategies, with active and visual learners showing the highest number for traditional design units. However, for the experimental design units, this selection changed with a lower number of students across all types of learning styles selecting collaborative team activity as their first choice with sensing, visual, sequential, and reflective learners showing the lowest numbers. Verbal learners' se-

Table 7: Students' Selection of Preferred Instructional Strategies for Experimental Design Units

Types of Learning Styles	Preferred Instructional Strategies (Frequency)
Reflective N = 5	• Real time/Synchronous Discussion (2) • Readings (2) • Multiple Instructional Materials (1) • Collaborative Team Activity (1)
Active N = 6	• Real time/Synchronous Discussion (3) • Collaborative Team Activity (2) • Multiple Instructional Materials (2)
Visual N = 9	• Multiple Instructional Materials (4) • Real time/Synchronous Discussion (4) • Collaborative Team Activity (1) • Readings (1)
Verbal N = 4	• Collaborative Team Activity (2) • Readings (1) • Real time/Synchronous Discussion (1)
Sensing N = 7	• Real time/Synchronous Discussion (3) • Readings (2) • Multiple Instructional Materials (1)
Intuitive N = 6	• Multiple Instructional Materials (3) • Collaborative Team Activity (2) • Real time/synchronous Discussion (1)
Sequential N = 7	• Real time/Synchronous Discussion (3) • Multiple Instructional Materials (2) • Collaborative Team Activity (1) • Readings (1)
Global N = 7	• Real time/Synchronous Discussion (3) • Readings (2) • Multiple Instructional Materials (1) • Collaborative Team Activity (1)

lection of collaborative team activity as their first choice remained the same for both traditional and experimental design units. Table 7 summarizes students' selection of preferred instructional strategies for experimental design units. As Tables 7 shows, except for verbal learners, students tended to select instructional strategies that appeared to be more aligned with their learning styles.

Again, this outcome confirms that availability of various instructional strategies during experimental design units resulted in students' use and selection of a variety of instructional strategies compared with traditional design. The results also suggest that students tended to select strategies that were more compatible with their learning styles. For instance, more visual learners tended to select multiple instructional materials compared with verbal learners who seem to prefer collaborative team activity, readings and real time discussions. However,

Table 8: Number and Period of Time That Students Read or Viewed Course Content and Materials

Tool	Traditional Units	Total Time	Experimental units	Total Time
Assignments	424	17:44:57	744	57:38:01
Chat	189	10:59:34	74	14:48:01
Content File	854	48:40:54	1152	47:11:44
Discussion	956	147:42:54	716	78:43:17
File Manager	87	7:07:35	153	11:25:43
Mail	718	59:51:50	834	72:33:01
Media Library	252	19:30:11	269	39:40:05
Organizer	15	0:53:53	1286	10:14:48

for the experimental design units, the following four multiple instructional strategies seemed to be perceived as more contributing to student learning: Multiple instructional materials (designed to address different learning styles), synchronous or real time discussion, collaborative team activity, and readings. As indicated earlier, students selected collaborative team activity, readings, and asynchronous discussion as their first choice for the traditional design units. This result indicates that while some strategies appear to be useful to all students with any learning styles (e.g., readings, problem solving, collaborative work with peers, real time discussion), students tend to become more selective if other strategies are readily available.

Analysis of the tracking system (see Table 8) showed that the number and period of time that students read or viewed postings in the forum discussion or used chat rooms to communicate with each other were reduced during experimental design units. However, the number and the period of time that students read or viewed assignments (collaborative team activity, reflective blog) and content related pages (lessons' objectives, readings, and instructional materials) increased for experimental design units. This result is not surprising because team activity and forum discussions were the only assignment related pages during traditional design units. Furthermore, while collaborative team activity, forum, and real time discussions were the core learning activities during traditional design units, individual reflective assignments and self-assessment quizzes combined with instructional materials in multiple formats were added to the list of learning activities for experimental design units. Thus, students had to spend more time browsing and reading assignments, assessments, and content related materials rather than focusing on discussion in chat rooms and discussion boards.

In order to examine whether there was any relationship between learning styles and the number of pages viewed, an analysis was conducted. The results indicated that reflective learners (83%) spent less time viewing/reading postings in the discussion board during experimental design units, compared to active learners (60%). In addition, both reflective and active learners spent more time viewing assignment pages during experimental design units, although they differed in viewing content related materials. Eighty three percent (83%) of reflective learners (20 to 99 times) spent more time viewing content related materials, compared with 60% of active learners (13 to 73 times) during experimental design units. Furthermore, while both visual and verbal learners spent more time viewing content related materials, visual learners (78%) spent considerably more time viewing content related pages (40 to 99 times more) during experimental design units. These findings suggest that learning styles may play a role in viewing pages when there is an option. However, since in this study students had to participate in all learning activities (matched and mismatched), flexibility was only available for ways in which students wanted to approach the learning tasks and for number and the periods of time they wanted to spend in exploring instructional materials. In addition, the increase in the use of matched instructional materials by participants might be due to the attempt in the experimental design to improve student knowledge of their own learning styles and to inform them of the instructor's effort to address their differences in the design of the experimental units. Although researchers do not seem to agree that student knowledge of his/her own learning style is likely to make much difference in his/her learning, they agree that if such knowledge is used by the instructor to encourage the learner to consider the nature of learning, understanding, and how he/she personally deals with the process, an impact may appear (e.g., Cuthbert, 2005; Jones, 1993; Perry, 1994).

Two open-ended survey items measured students' attitude and satisfaction for the units. One item asked students to explain their learning experiences for the units, and the other asked students to suggest changes to improve the learning experiences for the units. Students' responses at the end of traditional design units indicated that they had very positive learning experiences (e.g., "Very good. A solid start," "I would describe my learning experiences as being surprisingly effective," "I would describe my learning experience as very positive"). Students found readings interesting and considered collaborative team activity and real time discussion very effective strategies for learning (e.g., "The group discussions and the collaborative team activity helped to cement the material that was covered," "I am amazed at how much I can learn in an online class. I already feel like I have learned a lot," "I honestly feel that the real-time discussion and group project really cemented the concepts into my brain"). Students' suggestions for improvement can be summarized into four categories: combine the forum discussion for the two units, limit the length of the postings in the forum, spend more time on team activity, and add some individual assignments. The majority of reflective learners wanted to spend less time reading postings in the forum and responding, while the majority of active learners wished that they had more time to work with their team members on the team activity.

Students' responses to the attitude survey items at the end of the experimental design units indicated that they thought their learning experience was meaningful and they were challenged by the content of the units and learning activities. However, students appeared to be more divergent in their explanation of

Table 9: The Mean Scores for Team Products Completed During Traditional and Experimental Design Units.

Team Products		Mean	N	Std. Deviation	Std. Error Mean
Traditional Design	Team Activity 1	97.1429	14	4.68807	1.25294
	Team Activity 2	95.7143	14	5.83660	1.55990
Experimental Design	Team Activity 3	88.9286	14	8.58858	2.29540
	Team Activity 4	73.6429	14	23.58816	6.30420
Team Products (after removing the outlier)		**Mean**	**N**	**Std. Deviation**	**Std. Error Mean**
Traditional Design	Team Activity 1	96.3636	11	5.04525	1.52120
	Team Activity 2	94.5455	11	6.10514	1.84077
Experimental Design	Team Activity 3	91.3636	11	8.09040	2.43935
	Team Activity 4	84.7273	11	9.62383	2.90170

what they considered as positive learning experiences (e.g., I have found the information to be very challenging and complex," "Very much more in depth. Understanding is becoming easier," "I enjoyed the Merrill video as well as the interactive tutorials," "I felt that my learning experience was very meaningful," "Much more focused on constructing meaning rather than cramming in reading"). In addition, students did not suggest any major changes for the experimental design units and thought that the units were well designed ("I don't think I'd change anything at this point. Everything seems to be helping me," "I was happy with the design. I don't think I would change anything," "I would not change the format").

Descriptive analysis of student products of learning (team product, postings in the discussion board, individual reflective blogs) for traditional and experimental design units showed the following results. Table 9 summarizes the mean scores for team products completed during traditional and experimental design units. As Table 9 shows, students' mean scores were higher for both team products during the traditional design units, therefore, significantly different from experimental units ($t = 3.41 (df = 13); p=.005$). Closer inspection of the data showed that the low mean score for the second activity during the experimental design was due to an extreme low score (an outlier) for one team's product. The team's low score was due to an escalated conflict among team members, which was reported to the instructor but it could not be resolved before the team submitted its products. Removing the outlier team from the data, however, did not affect the results and student performance indicated that students achieved higher scores during traditional design units ($t = 3.42$ ($df = 10$); $p = .007$), although the mean scores for the team products during experimental design were higher after removing the outliers.

The mean scores for student postings in the discussion board during traditional ($M = 34.2$) and experimental design ($M = 35.5$) showed no statistically

Table 10: Reflective and Active Students' Average Scores for Postings in the Discussion Boards

Learning Styles	Students	Traditional Design	Experimental Design
		Discussion Postings Mean	Discussion Postings Mean
Reflective	1	49.5	33.5
	2	27	28.5
	3	30.5	57.5
	4	47	35
	5	23	27
	6	19	7.5
Average Score		32.75	31.5
Active	1	43.5	52.5
	2	28	41.5
	3	38	51
	4	33.5	26
	5	35	45
Average Score		35.6	43.2

significant difference ($t = -.349$ ($df = 13$); $p = .733$). Analysis of students' scores for their postings in the discussion board across different types of learning styles, however, pointed to some differences. While 80% of active learners scored higher for their postings during experimental design units (see Table 10) only 50% of reflective learners showed this pattern of change. In addition, active learners scored higher for their postings in both traditional and experimental design units compared with reflective learners. Active learners' higher performance in discussion boards may not be a surprise since according to learning style theory, active learners tend to be more compatible with instructional strategies that provide an opportunity for group discussion and sorting of ideas. Similar results were shown in previous studies conducted by Felder, Felder, and Diatz (2002), McCaulley, Godleski, Yokomoto, Harrisberger, and Sloan (1983) and Rosati (1997).

Two activities could explain the improvement in active learners' performance for experimental design units. First, active learners had an opportunity to complete individual blogs. This activity allowed students to reflect on reading materials while participating in asynchronous discussion (a mismatched strategy for their learning style). In addition, active learners, who were also visual in their style, had access to multiple instructional materials, and could select the materials that were matched with their learning styles. Visual and verbal learners' scores, as well as sequential and global and intuitive and sensing learners' scores, did not show any major changes across traditional and experimental design units.

Table 11: Students' Average Scores on Individual Blogs Across Different Types of Learning Styles

Style	Students	Blogs (M)	Styles	Blogs (M)	Style	Blogs (M)	Style	Blogs (M)
Reflective N = 6	1	100	**Active** N = 5	100	**Visual** N = 9	93	**Verbal** N = 4	100
	2	100		83		100		100
	3	70		60		70		100
	4	96.5		53.5		93.5		87
	5	100		80		96.5		
	6	87				83		
	7					60		
	8					53.5		
	9					80.0		
Average Score		**92.3**		**75.3**		**81.1**		**96.75**

Analysis of student performance for individual reflective blogs during experimental design units pointed to some differences among students with different learning styles. Reflective and verbal learners scored higher compared with active and visual learners (see Table 11), although the difference was not significant. This result was confirmed by visual and active learners' comments that they did not like writing blogs and found it to be a difficult task. Given characteristics of reflective and verbal learners, this result is expected and consistent with learning styles theories and research (e.g., Felder, Felder, & Diatz, 2002; Kolb, Boyatzis, & Mainemeli, 2000).

Limitations of the Study

The present study has certain limitations that need to be taken into account when considering the study and its contributions. However, some of these limitations can be seen as fruitful avenues for future research under the same theme.

The selection of the single case design naturally brings forth limitations as far as the generalization of the results of the study is concerned. The sample size was particularly small and the participants were not representative of a broad population of graduate students. Furthermore, short exposure durations for both traditional and experimental design units and exclusive reliance on two units of instruction could have influenced the results. Given the controversy in the literature surrounding this issue, future studies should consider cross sectional design, longer exposure to instruction and instructional materials, larger and more diverse sample size, and various subject matters.

CONCLUSIONS AND IMPLICATIONS

Designing and developing instructional materials that address multiple learning styles and employing various instructional strategies for online learning environments are time consuming and require careful design, development, implementation and evaluation of instruction. The results of this study shed light on whether or not such an attempt is worthy of time and effort. Furthermore, while many studies show that matching student learning styles with instructional strategies improves learning, some instructional designers and educators argue that content and expected outcomes of learning must decide what strategies should be used to deliver instruction, rather than matching instruction to individual learning styles (Merrill, 2000).

The results of this study and the model that was used to design instruction for multiple learning styles provide evidence that factors such as learning tasks and the context in which learning is to transpire (e.g., student level of engagement in the learning process, level of interactivity among students and between student and the instructor, and instructor immediacy behavior) and student's perception of social presence (social and human qualities of online learning) (Hackman & Walker, 1990) may play a more significant role in improving instructional effectiveness in online learning. The comparison between traditional and experimental design units pointed to a significant difference in student learning in favor of a traditional design approach, but it did not show a major difference in student satisfactions. In addition, some changes in student interaction with various self-instructional materials (student-content interaction) and students' perception of their depth of learning were observed. It appeared that multiple forms of interactivity, including synchronous virtual classroom discussion during traditional design units, combined with student engagement in collaborative problem solving activities, helped students adjust their strategic approaches to learning in order to achieve expected learning outcomes without impacting their attitude and satisfaction. In other words, it seems that in online learning environments where social interaction, collaboration and problem solving are highly emphasized, it is likely that students' perception of their positive learning experience influence their motivation and willingness to adjust their preferred learning styles. This result has been supported by researchers who have studied teaching and learning in online learning environments (e.g., Garrison, Anderson, & Archer, 2000; Wenger, 2001). For example, after reviewing literature on interactions in online learning, Anderson (2002) postulates that "sufficient levels of deep and meaningful learning can be developed as long as one of the three forms of interaction (student-teacher; student-student; student-content) are at very high levels" (n.p.). In addition, it is also likely that a collaborative problem solving activity, as a learning task, is not an antithetical strategy that causes learners with different learning styles to feel too uncomfortable to learn effectively. Rather, it is possible that the problem solving strategy creates an open learning environment in which students are able to employ a full range of learning skills and strategies (Smith & Renzulli, 1984). Finally, the insignificant difference in some performance results may also suggest that student perception of social presence (quality of human interaction) might have as large an impact on students' motivation for learning and their level of effort and engagement in traditional design units as offering various instructional strategies for different learning styles. However, it should be noted that the above-mentioned results in this study could have been influenced by participants' backgrounds and experiences, as well as the course subject matter. In addition, since participants in this study only were exposed to traditional design units for two weeks, it is not clear if their attitude and satisfaction would have stayed positive if all course units were designed using the traditional approach. Future studies should focus on diverse groups of learners and various subject matters. Teaching two courses with similar content and learner populations should be used as experimental and control groups in order to be able to generalize the above mentioned results.

In spite of the significant difference in student learning in favor of traditional design units, the results of this study suggest that learning styles can be integrated into instruction in online learning environments without compromising the appropriateness of instructional strategies for specific content and learning outcomes. The match and mismatch strategy combined with Kolb's (1984) Learning Cycle model employed in the design and organization of the experimental units appears to provide enough flexibility and learner control, yet opportunities for students to learn in a most effective manner. The point of using learning styles in the design of experimental units in this study was not to determine each student's preferred instructional approach (visual or verbal, sensing or intuitive, etc.) nor to provide instruction exclusively in that manner. Rather, it was designed to (1) address students' preferences by providing enough control and flexibility in the ways they are more comfortable to learn, and (2) require students to function in their less preferred approach by allowing them to begin their learning cycle in the manner that they preferred. The results suggest that even though measures of student learning do not point to any major differences, there are some qualitative differences in student approaches to learning when learning styles are considered. For instance, while writing reflective journals and interacting with readings and other instructional materials were preferred learning strategies for reflective learners, active learners seemed to benefit from engaging in such activities. On the other hand, while collaborative work and group discussion were not favored by reflective learners, they seemed to agree that these activities contributed to their learning. Furthermore, integrating learning styles in the design of instructional materials seemed to encourage learners to spend more time interacting with the course content and exploring various instructional materials to achieve learning outcomes. Although social presence is often set in synchronous or asynchronous activities in online learning, it can also be set through audio-, video-, or text-based presentations. Direct instruction can also be provided through an instructor's annotations of the scholarly work of others and notes. If addressing multiple learning styles through a variety of instructional strategies could result in improving student interaction with the course content, it may very well result in higher learning outcomes, as participants in this study commented. The future research should use measures of learning outcomes that assess students' deep understanding of underlying concepts, in addition to the applications of these concepts in practice, as used in this study. Such measures might better discriminate between deep versus shallow concept learning that is likely to result from being exposed to a full range of interactions during experimental design.

The match/mismatch strategy used in this study required students to expand their learning preferences by engaging in different learning activities. Whether or not this strategy helped learners modify their learning styles and become more balanced learners was not examined in this study. Long term studies are needed to determine whether balanced instructional strategies help learners expand their learning styles. The instructional effectiveness of applying the design model used in this study will be reinforced if such results are confirmed by studies with a larger sample size. Many learning styles theorists argue that today's increasingly more complex and service-oriented jobs demand flexibility in learning approaches for success (Kolb, Boyatzis, & Mainemeli, 2000). Therefore, more studies are needed to show whether or not people with balanced learning profiles are more sophisticated or adaptively flexible learners.

Finally, this study confirms that integrating learning styles into the design of instruction in online learning is possible and will change significantly the design role of online instructors from one of content creation to one of customization, application, and contextualization of learning sequences (Koper, 2001). The findings also suggest that integrating student preferences for learning helps the course designers to improve interactivity and social presence in online learning environments.

Contributor

Mahnaz Moallem is a professor of instructional technology and research and program coordinator for the Instructional Technology Graduate program at the University of North Carolina, Wilmington, Watson School of Education. She is currently on a two-year reassignment at the National Science Foundation, serving as an instructional technology project leader. (Address: Watson School of Education, Dept. Instructional Technology, Foundations & Secondary Education, 601 South College Road, Wilmington, NC 28403; Phone: 910.962.4183; Fax: 910.962.3609; moallemm@uncw.edu)

References

Anderson, T. (2002). Getting the mix right: An updated and theoretical rationale for interaction. *ITFORUM*, *Paper #63.* Retrieved July 5, 2006, from http://it.coe.uga.edu/itforum/paper63/paper63.htm

Apter, M. J. (2001). *Motivational styles in everyday life: A guide to reversal theory*, Washington DC: American Psychological Association.

Atkinson, S. (1998). Cognitive style in the context of design and technology work. *Educational Psychology*, *18*(2), 183–194.

Baldwin, L, & Sabry, K. (2003). Learning styles for interactive learning systems. *Innovations in Education and Teaching International, 40*(4), 325–340. ISSN 1470-3297.

Barbe, W. B., & Milone, M. N. (1981). What we know about modality strengths. *Educational Leadership*, *38*(5), 378–380.

Berliner, D. C. (1979). Tempus educare. In P. L. Peterson & H. J. Walberg (Eds.), *Research on teaching: Concepts, findings and implications* (pp. 120–135). Berkeley, CA: McCutchan Pub.

Biggs, J. B. (1979). Individual differences in study processes and the quality of learning outcomes. *Higher Education*, *8*, 381–394.

Biggs, J. B. (1987). *Student approaches to learning and studying*. Hawthron, Australia: Australian Council for Educational Research.

Biggs, J. B. (1992). *Why and how Hong Kong students learn? Using the Learning and Study Process Questionnaires* (Education Paper No. 14). Hong Kong: Faculty of Education, The University of Hong Kong.

Biggs, J. B., & Moore, P. J. (1993). *The process of learning* (3rd ed.). Englewood Cliffs, N.J.: Prentice Hall.

Canino, C., & Cicchelli, T. (1988). Cognitive styles, computerized treatments on mathematics achievement and reaction to treatments. *Journal of Educational Computing Research*, *4*(3), 253–64.

Carroll, J. B. (1989). The Carroll model: A 25 year retrospective and prospective view. *Educational Researcher*, *18*(1), 26–31.

Claxton, C. S. & Murrell, P. M. (1987). *Learning styles: Implications for improving educational practices.* ASHE-ERIC/Higher Education Report No. 4. Washington, D.C.: George Washington University.

Claxton, S. & Ralston, Y. (1978). *Learning styles: Their impact on teaching and administration* (Higher Education Report, No. 10), Washington DC: American Association for Higher Education.

Cornett, C. E. (1983). *What should we know about learning styles*? Fastback 191, Bloomington, IN: Phi Delta Kappa Educational Foundation.

Corno, L., & Snow, R. E. (1986). Adapting teaching to individual differences among learners. In M. Wittrock, (Ed.), *Handbook of Research on Teaching* (pp. 605–629). New York: Macmillan.

Cuthbert, P. F. (2005). The student learning process: Learning styles or learning approaches. *Teaching in Higher Education*, *10*(2), 235–249.

De Vita, G. (2001). Learning styles, culture and inclusive instruction in the multicultural classroom: A business and management perspective. *Innovations in Education and Teaching International*, *38*(2), 165–174.

Dunn, R. (1995). *Strategies for educating diverse learners*. Bloomington, IN: *Phi Delta Kappan Educational Foundation* FASTBACK Series #384.32

Dunn, R. (1999). How children learn: How learning styles impact student achievement. *Girls' Fast-Pitch Softball and Education Magazine 1*(1), 5–8.

Dunn, R., & Dunn, K. (1978). *Teaching students through their individual learning style*. Englewood Cliffs, N J: Prentice-Hall.

Dunn, R., Beaudry, J.S., & Klavas, A. (1989). Survey of research on learning styles. *Educational Leadership*, *46*, 50–58.

Entwistle, N. (1981). *Styles of teaching and learning: An integrated outline of educational psychology for students, teachers, and lecturers*. New York, NY: John Wiley & Sons.

Entwistle, N., & Ramsden, P. (1983). *Understanding student learning*. London: Crumb Helm.

Felder, R. (1993). Reaching the second tier: Learning and teaching styles in college of science education. *Journal of College Science Teaching, 23*(5), 286–290.

Felder, R. M. & Henriques, E. R. (1995). Learning and teaching styles in foreign and second language education. *Foreign Language Annals*, *28*(1), 21–31.

Felder, R. M. & Silverman, L. (1988). Learning and teaching styles in engineering education. *Engineering Education, 78*(7), 674–681.

Felder, R. M., & Soloman, B. A. (1998). *Index of learning styles*. Online version of the questionnaire available at North Carolina State University: http://www2ncsu.edu/felder-public/ILSdir/ILSweb.html.

Felder, R. M., Felder, G. N., & Dietz, E. J. (2002). The effects of personality type on engineering student performance and attitudes. *Journal of Engineering Education, 91*(1), 3–17.

Ford, N., & Chen, S. Y. (2001). Matching/mismatching revisited: An empirical study of learning and teaching styles. *British Journal of Educational Technology, 32*(1), 5–22.

Gardner, H. (1983). *Frames of Mind*. New York: Basic Books Inc.

Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical thinking in text-based environment: Computer conferencing in higher education. *The Internet and Higher Education*, *2*(2), 87–105.

Grasha, A. F. (1996). *Teaching with style: A practical guide to enhancing leaning by understanding teaching and learning styles*. Pittsburgh: Alliance Publishers.

Gregorc, A. F. (1985). I*nside styles: Beyond the basics*. Maynard, MA: Gabriel Systems.

Gregorc, A. F. & Butler, K. A. (1984). Learning is a matter of style. *Vocational Education*, *59*(3), 27–29.

Grigorenko, E. L., & Sternberg, R. J. (1995). Thinking styles. In D. H. Sakloske & M. Zeidner (Eds.), *International handbook of personality and intelligence* (pp. 205–230). NY: Plentum.

Hackman, M. Z., & Walker, K. B. (1990). Instructional communication in the televised classroom: The effects of systems design and teacher immediacy on student learning and satisfaction, *Communication Education*, *39*(3), 196–206.

Hermann, N. (1996). *The whole brain business book*, New York: McGraw Hill.

Hill, J. S. (1976). *Cognitive style interest inventory*. Bloomfield Hills, MI: Oakland Community College Press.

Honey, P. & Mumford, A. (1982). *The manual of learning styles*. Maidenhead, UK: Honey.

Honey, P. & Mumford, A. (1986). *Using your learning styles*. Maidenhead, UK: Honey.

Hudak, M. A. & Anderson, D. E. (1984). Teaching style and student ratings. *Teaching of Psychology, 11*(3), 177–178.

Hudak, M.A. (1985). Review of learning styles inventory. In D. J. Keyser & R. C. Sweetland (Eds.), *Test Critiques* (Vol. II, pp. 402–410). Kansas City, Missouri: Test Corporation of America.

Jonassen, D. (1988). Integrating learning strategies into courseware to facilitate deeper processing. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 151–182). Hillsdale, NJ: Lawrence Erlbaum.

Jonassen, D. H., & Grabowski, B. L. (1993). *Handbook of individual differences, learning, and instruction*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Jonassen, D. H., & Wang, S. (1993). Acquiring structural knowledge from semantically structured hypertext. *Journal of Computer-based Instruction*, *20*(1), 1–8.

Jones, S. (1993). Cognitive learning styles: Does awareness help? A review of selected literature. *Language Awareness*, *2*(4), 195–207.

Kagan, J. (1976). Commentary on reflective and impulsive children: Strategies of information processing underlying differences in problem solving. *Monographs of Society for Research in Child Development*, *41*(5), Serial No. 168.

Kim, J., & Michael, W. B. (1995). The relationship of creativity measures to school achievement and preferred learning and thinking style in a sample of Korean high school students. *Educational and Psychological Measurement*, *55*, 60–71.

Kolb, D. A. (1979). *The learning style inventory: Technical manual*. Boston, MA: McBer & Co.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. NJ: Prentice Hall.

Kolb, D. A. (1985). *Learning style inventory: Self-scoring inventory and interpretation booklet* (2nd ed.). Boston: McBer & Co.

Kolb, D. A., Boyatzis, R. E., & Mainemeli, C. (2000). Experiential learning theory: Previous research and new directions. In R. J. Sternberg & L. F. Zhang (Eds.), *Perspectives on cognitive, learning, and thinking styles* (pp. 2–40). NJ: Lawrence Erlbaum.

Kolb, D. A., & Fry, R. (1975). Toward an applied theory of experiential learning. In C. Cooper (Ed.), *Theories of Group Process* (pp. 33–58). London: John Wiley.

Kolb, D. A. (1976) *The learning style inventory: Technical manual*, Boston, MA: McBer.

Koper, R. (2001). *Modeling units of study from a pedagogical perspective: The pedagogical meta-model behind EML.* Heerlen, Netherlands: Open University of the Netherlands. Retrieved July 5, 2006, from http://eml.ou.nl/introduction/docs/ped-metamodel.pdf.

Lovelace, M. K. (2005). Meta-analysis of experimental research based on the Dunn and Dunn Model. *Journal of Educational Research*, *98*, 176–183.

Matthews, D. B. (1991). The effects of learning styles on grades of first-year college students. *Research in Higher Education*, *32*(3), 253–268.

McLoughlin, K. (1999). The implications of the research literature on learning styles for the design of instructional material. *Australian Journal of Educational Technology*, *15*(3), 222–241.

McCaulley, M. H., Godleski, E. S. Yokomoto, C. F., Harrisberger, L., & Sloan, E. D. (1983). Applications of psychological type in engineering education. *Engineering Education*, *73*, 394–400.

Merrill, M. D. (2000). Instructional strategies and learning styles: Which takes precedence? In R. Resier & J. Dempsey (Eds.), *Trends and issues in instructional technology* (pp. 99–106). New York: Prentice Hall.

Moore, M. G. (1989). Three types of interaction (Editorial). *The American Journal of Distance Education, 3*(2), 1–7.

Myers, I. B. (1980). *Gifts differing*. Palo Alto, CA: Consulting Psychologists Press.
Myers, I. B., & McCaulley, M. H. (1988). *Manuals: A guide to development and use of the Myers-Briggs type indicator*, Palo Alto, CA: Consulting Psychologist Press.
Pask, G. (1988). Learning strategies, teaching strategies, and conceptual or learning style. In R. Schmeck, (Ed.), *Learning Strategies and Learning Styles* (pp. 83-100) NY: Plenum Press.
Perry, C. (1994). *Students' learning styles: Implications for teacher education*, Brisbane, Queensland, Australia: Annual Convention of Australian Teacher Education Association. (ERIC Document Reproduction Service No. ED 375136).
Pinto, J. K., Geiger, M. A., & Boyle, E. J. (1994). A three year longitudinal study of changes in student learning styles. *Journal of College Student Development*, *35*(2), 113–119.
Price, G. E (1980). Which learning style elements are stable and which tend to change over time? *Learning Styles Network Newsletter*, *1*(3), 1.
Rasmussen, K. L. (1998). Hypermedia and learning styles: Can performance be influenced? *Journal of Multimedia and Hypermedia*, *7*(4), 291–308.
Rector, R. E., & Henderson, K. B. (1970). The relative effectiveness of four strategies for teaching mathematical concepts. *Journal for Research in Mathematics Education, 1*, 69–75.
Riding, R., & Grimley, M. (1999). Cognitive style and learning from multimedia materials in 11-year children. *British Journal of Educational Technology*, *30*(1), 43–59.
Rosati, P. (1997). Psychological types of Canadian engineering students. *Journal of Psychological Type, 41*, 33–37.
Rowntree, D. (1992). *Exploring open and distance learning materials*. London: Kogan Page.
Sadler-Smith, E. (2001). Three or four learning styles? A reply to Swailes and Senior, *International Journal of Selection and Assessment*, vol.9, pp. 207–214.
Saracho, O. N. (1993). Sociocultural perspectives in the cognitive styles of young students and teachers. *Early Child Development and Care*, *84*, 1–17.
Schmeck, R. R. (Ed) (1988). *Learning strategies and learning styles*. NY: Plenum Press.
Smith, L. H., & Renzulli, J. S. (1984). Learning style preferences: A practical approach for classroom teachers. *Theory into Practic*e, *23*, 44–50.
Solomon, B. A., & Felder, R. M. (2002). *Index of Learning Styles,* Retrieved January 5, 2007 from *http://www.ncsu.edu/felder-public/ILSpage.html.*
Sternberg, R. J. (1997). *Thinking styles.* Cambridge, UK: Cambridge University Press.
Sternberg, R. J., & Grigorenko, E. (1995). Styles of thinking in the school. *European Journal for High Ability*, *6*, 201–219.
Sternberg, R. J. (1998). *Thinking styles*, New York: Cambridge University Press.
Watkin, H. A. (1978). Cognitive styles in personal and cultural validation of models of student learning. *Educational Psychology*, *16*, 317–327.

Wenger, E. (2001). *Supporting communities of practice: A survey of community-orientated technologies*. (1.3 ed.). Shareware. Available at http://www.ewenger.com/tech/

Wiggins, G. P. & McTighe, J. (2005). *Understanding by Design* (Expanded 2nd Edition). Alexandria, VA: ASCD.

Witkin, H. A., Moore, C. A., Goodenough, D. R., & Cox, P. W. (1977). Field dependent and field independent cognitive styles and their educational implications. *Review of Educational Research*, *47*, 1–64.

Yin, R. K. (1994). *Case study research design and methods* (2nd edition). Beverly Hills, CA: Sage Publishing.

Zhang, L. F. (1999). Further cross-cultural validation of the theory of mental self-government. *The Journal of Psychology*, *133,* 165–181.

Zhang, L. F. (2002). Thinking styles: Their relationships with modes of thinking and academic performance. *Educational Psychology*, *22*(3), 331–348.

Zhang, L. F., & Sternberg, R. J. (1998). Thinking styles, abilities, and academic achievement among Hong Kong University students. *Educational Research Journal*, *13*, 41–62