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Student Learning Styles Adaptation Method Based on Teaching Strategies and Electronic Media

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ABSTRACT

Recent research on the learning process has shown that students tend to learn in different ways and that they prefer to use different teaching resources as well. Many researchers agree on the fact that learning materials shouldn't just reflect of the teacher's style, but should be designed for all kinds of students and all kind of learning styles. Even though they agree on the importance of applying these learning styles to different learning systems, various problems still need to be solved, such as matching teaching contents with the student's learning style. In this paper, we describe the design of a personalized teaching method that is based on an adaptive taxonomy using Felder and Silverman's learning styles and which is combined with the selection of the appropriate teaching strategy and the appropriate electronic media. Students are able to learn and to efficiently improve their learning process with such method.

Keywords

Adaptability, electronic media, learning styles, teaching strategies

Introduction

Humans have different ways of learning. Some can assimilate in a better way the knowledge received visually, auditory or through a certain sense. Psychology and cognitive sciences have longtime explored this question. The Dual Coding Theory for example states that information is processed through one of two usually independent channels (Beacham et al., 2002). While one channel processes verbal information such as text or audio, the other one processes visual information like diagrams, images, animations, etc. The Sperry's Nobel Prize winning left-brain / right-brain model of thinking suggested that the right hand side and the left hand side of our brain possessed specialized and differentiated functions (Dervan, et al. 2006). The left cerebral hemisphere is thought to be more verbal, logical or clinical, that is, more analytical, while the right cerebral hemisphere influences more the artistic and the sensing side of our intellectual. Powerful encoding and visualization techniques have shown to enable the creation lasting memory and improve recall. Dual encoding, for example, has proven to be an extremely effective learning tool. The simplest and most common form of which involves presenting the information both textually and visually. "Whole brain" learning is known to be a far more effective way to learn. The better connected the two halves of the brain, the greater the potential of the brain for learning and creativity (Rose, 1998; Dervan, et al. 2006). However, most educational systems have ignored individual differences that exist between learners, such as the learning ability, the background knowledge, the learning goals and the learning style (Ford & Chen, 2001). Educational systems generally provide a unique and standardized teaching material to all learners which tend to benefit to those whose learning style and background knowledge fits well with the teaching material. If the teaching style employed closely matches the student preferred style of acquiring knowledge, learning becomes easier and more natural, results improve and learning time is reduced (Rose, 1998). On the other hand, if for example a student is more visual than verbal and everything is written on the blackboard without auditory resources, student will experience difficulties in attaining the pedagogical goals in the requested time. In few words, traditional teaching material and strategies generally tend to benefit some students more than others.

In this sense, it is necessary to deploy resources to support the learning process in a way that it not only suits the characteristics of a few, but that it adapts to the characteristics of each student. In the context of Information Technology evolution and the availability of large number of electronic media, the idea of matching e-media with appropriate teaching and learning styles has been explored since the late 90's. There are many studies on the effectiveness of combining multimedia and hypermedia with learning styles in educational systems (Najjar, 1996)

(Liao, 1999). They attempt to associate specific e-media characteristics to different categories of learners and propose instruments and methods for assessing learning style (Riding & Rayner, 1998). Most of these studies rely on Kolb's Learning Styles Inventory (LSI) (Kolb 1984) and Soloman-Felder Index of Learning Styles (ILS) (Soloman, & Felder, 1993).

However, very few researchers give an idea of which appropriate combinations of electronic media and learning styles are more effective than others. An electronic media can be used in different ways to implement different teaching strategies which can be matched with different learning styles. For example, a discussion forum can be used in different ways. It can be used to assign a practical task to students in such a way that students solve the assigned problem in a collective manner. This fits well with sensitive learning style. The discussion forum can also be used to give a sequential series of theoretical presentations to students who can interact with the teacher. The sequence of presentations associated with the corresponding discussion is an adequate teaching material for sequential style students.

The objective of our research work is the creation of teaching methods and environments that use the vast resources offered by IT in such a way to adapt teaching material and strategies to the learner's skills and learning style. We use Felder & Silverman (1988) model for defining learning style, together with empirically built adaptation taxonomy for matching e-media with combinations of teaching strategies and learning styles. In a previous work, we explored some basic ideas concerning the matching of e-media and learning styles in the context of an experimental e-learning system (Franzoni & Assar, 2007). In this paper, we present a general framework for combining and adapting teaching strategies, learning styles and electronic media. This taxonomy has been experimented in an undergraduate computer science course. First results show that a majority of students have a better assimilation of knowledge and that students appreciated positively the personalized pedagogical material proposed in the course.

The rest of the paper is organized as follows. First, we present related works concerning existing adaptation techniques for adapting learning styles with e-media. Second, we present the pedagogical bases of our work. The third section introduces the adaptive teaching taxonomy with the underlying model. Fourth, the method for applying the adaptive taxonomy is described and illustrated in a teaching experiment. Finally, concluding remarks and comments are presented together with directions for future work.

Related works

Recent investigations [(Kwok & Jones 1985), (Carver et al., 1999), (Gilbert & Han 1999), (Grigoriadou, Papanikolaou & Kornilakis 2001), (Stash & De Bra 2004), (Hong & Kinshuk 2004)], try to integrate the learning styles and e-media in the design of their applications. This is not an easy process, however. One of the main difficulties on the designing of hypermedia systems, is linking the learning styles with the hypermedia applications. Most of the teaching systems adaptation that integrates learning styles is based on the premise that adapting the teaching strategies with the students' learning styles will give better results (Dagger, Wade & Conlan 2003), (Paredes & Rodriguez 2002), (Stern & Woolf 2000), (Triantafillou, Pomportsis & Georgia 2002). Table 1 shows some of the systems found, their learning styles and the type of adaptation.

Table 1. Learning Styles and Systems Adaptation Models

System	Learning style	The adaptation Model	The adaptation behavior
ARTHUR (Gilbert & Han 1999)	visual-interactive, auditory-lecture and text styles	The adaptation is achieved by providing different media representations for each learner. *Auditory* representation is achieved using sounds and streaming audio. To appeal to *visual* and *kinesthetic* learners puzzles, animations, drag and drop examples and riddles are used.	Type and usually the sequencing of material they offer based on a framework proposed by the authors
CS388 (Carver, Howard &	Felder-Silverman learning styles model global-sequential, visual-verbal,	The adaptation is achieved by providing different media representations for each learner. Uses	Based on research studies, (Felder and Silverman, 1988) about the

Lane 1999)	sensing-intuitive, inductive-deductive styles (Felder & Silverman, 1988)	different types of media such as graphs, movies, text, slideshows	type of instructional material that learners with different learning style prefer
MANIC (Stern & Woolf 2000)	applies preferences for graphic versus textual information	The adaptation is achieved by providing different media representations for each learner. Uses graphic and textual information	Type and usually the sequencing of material they offer based on a framework proposed by the authors
INSPIRE (Grigoriadou, Papanikolaou & Kornilakis 2001)	Honey and Mumford categorization of activists, pragmatists, reflectors and theorists based on Kolb (Honey & Mumford, 1992)	The Adaptation lies in presenting a different sequence of alternative contents of the concepts. Concepts can be represented by 'example', 'activity', 'theory', 'exercise'	Based on research studies (Honey & Mumford, 1992), about the type of instructional material that learners with different learning style prefer (Papanikolaou et al., 2003)
Tangow (Paredes & Rodríguez 2002)	sensing-intuitive dimension from the Felder-Silverman learning style model (Felder & Silverman, 1988)	The Adaptation lies in presenting a different sequence of alternative contents of the concepts. Concepts can be represented by 'example', 'exposition'	Type and usually the sequencing of material they offer based on a framework proposed by the authors
AES-CS (Triantafillou, Pomportsis & Georgia 2002) (Triantafillou et al., 2003)	field-dependent (FD) and field-independent (FI) style (Witkin et al., 1977)	Provides *field-dependent* learners with navigational support tools, such as concept map, graphic path indicator, advanced organizer, in order to help them organize the structure of the knowledge domain. The system guides them through the learning material via adaptive navigation support. *Field-independent* learners are provided with a learner control option - for them, the system shows a menu from which they can proceed with the course in any order. Learners can switch between different instructional strategies	Adopts several instructional strategies that accommodate learners' learning style in relation with: the approaches, the control options, the contextual organizers, the study instructions, the feedback, and the lesson structure.
PHP Programming Course (Hong & Kinshuk 2004)	Active – Reflective, Sensing – Intuitive, Visual – Verbal, Sequential - Global dimension from the Felder-Silverman learning style model (Felder & Silverman, 1988)	The adaptation is achieved by providing different representations for each learner. Uses different types of resources such as concepts, theory, colors, text, slideshows, audio, etc.	Based on research studies, (Felder and Silverman, 1988) about the type of instructional material that learners with different learning style prefer

This review shows that the different adaptation to learning styles systems are done in terms of content adaptation, navigation routes or the use of multiple navigation instruments. However, the election of learning styles seems to be limited, while it is based on the appropriate technology. Also, most of the systems shown, except CS388 and PHP Programming Course, evaluate and adapt to the chosen learning styles dimensions. One disadvantage of CS388 and the PHP Programming Course is that electronic media is limited to graphics, hypertext, audio and video, and that it doesn't integrate teaching strategies. In this sense, this work is new and significantly different from the previous efforts done by others in the field.

Pedagogic Model

Learning Styles Model by Felder-Silverman

A learning style is defined as the characteristics, strengths and preferences in the way people receive and process information (Felder & Silverman 1988). It refers to the fact that every person has its own method or set of strategies when learning. According to Sewall, there are several theories about learning styles (Sewall, 1986). He did a detailed study of four learning styles evaluation instruments: Myers-Briggs Type Indicator, Kolb's Learning Style Inventory, Canfield's Learning Style Inventory and Gregorc's Type Indicator.
We have selected the Felder and Silverman model as the basis of our taxonomy of adaptive teaching for the following reasons:

- it has been successfully implemented in previous work when individually adapting the electronic learning material (Carver, Howard & Lane, 1999), (Hong & Kinshuk, 2004), (Paredes & Rodriguez, 2002),
- it has been approved by it's author and other specialists (Zywno, 2003) (Felder & Spurlin, 2005),
- it is user friendly and the results are easy to interpret,
- the number of dimensions is controlled and can actually be implemented (Paredes & Rodriguez, 2002).

This model rates the student's learning style in a scale of four dimensions. Each learning style can be defined by answering these four questions:

1. What kind of information does the student tend to receive: sensitive (external agents like places, sounds, physical sensations), or intuitive (internal agents like possibilities, ideas, through hunches)?
2. Through which sensorial channel do the students tend to receive information more effectively: visual (images, diagrams, graphics), or verbal (spoken words, sounds)?
3. How is the information processed: actively (through physical activities and discussions), or reflexively (through introspection)?
4. How does the student make progress: sequentially (with continuous steps), or globally (through leaps and an integral approach)?

Table 2 shows the learning styles dimensions (LSD) that resulted from the latter questions:

Table 2. Felder Learning Styles Dimensions

Learning Style Dimension	Type	Description
Perception (**LSD1**)	Sensitive (**S**)	Rather deal with facts, raw data and experiments, they're patient with details, but don't like complications
	Intuitive (**I**)	Rather deal with principles and theories, are easily bored when presented with details and tend to accept complications
Entry Channel (**LSD2**)	Visual (**Vi**)	Easy for them to remember what they see: images, diagrams, time tables, films, etc.
	Verbal (**Ve**)	Remember what they've heard, read or said.
Processing (**LSD3**)	Active (**A**)	Learn by working in groups and handling stuff
	Reflexive (**Re**)	Learn better when they can think and reflect about the information presented to them. Work better alone or with one more person at most.
Understanding (**LSD4**)	Sequential (**Seq**)	Follow a lineal reasoning process when solving problems and can work with a specific material once they've comprehended it partially or superficially
	Global (**G**)	Take big intuitive leaps with the information, may have a difficulty when explaining how they got to a certain result, need an integral vision

Teaching Strategies

Considering that pedagogy includes teaching and learning strategies, we will provide a definition of both. Learning strategies are the strategies used to remember, learn and use information. In this case, responsibility relies on the

student (comprehension and text writing, problem solving, etc.). Students go through a process where they recognize the new knowledge, review previous concepts, organize and restore that previous knowledge, match it with the new one, assimilate it and interpret everything that was seen on the subject.

Teaching strategies (TS) are the elements given to the students by the teachers to facilitate a deeper understanding of the information. The emphasis relies on the design, programming, elaboration and accomplishment of the learning content. Teaching strategies must be designed in a way that students are encouraged to observe, analyze, express an opinion, create a hypothesis, look for a solution and discover knowledge by themselves. Didactic teaching strategy for example refers to an organized and systematized sequence of activities and resources that teachers use while teaching. The main objective is to facilitate the students´ learning.

Among the different components of a teaching strategy, we can mention the way of developing the learning process, and the means and resources used. In this sense, some of the previous studies worth mentioning are for example those of Dunn (1988), who insists on the importance of teaching the students by using methods that adapt to their conceptual preferences. Or Cabrero (2006), who also points out how the applied teaching strategies will take effect on the teaching quality, not only from an individual point of view, but also on the collaboration of the group as a whole.

One crucial aspect of our research is the integration of electronic media with teaching strategies, because of the informational technology breakthroughs that allow us to use a variety of them. On the other hand, we need to link such teaching strategies with the concept of learning styles, something that hasn't been exploited to the extent that is intended here. The teaching strategies for this case are in table 3.

Table 3. Teaching strategies (TS)

Teaching Strategies
TS1 = Games and simulations
TS2 = Learning based on problem solving
TS3 = Role playing
TS4 = Presentation
TS5 = Discussion panel
TS6 = Brainstorming
TS7 = Case study
TS8 = Question and answer method
TS9 = Project design method

Adaptive Teaching Taxonomy

One usual definition of taxonomy is the following: "*it is the science of orderly classification in natural history*" (Bloom, 1971). Teaching taxonomy seeks to provide the foundations for a classification of the goals within a teaching system (i.e. classification of the desired behavior of the student). From the point of view of the teaching strategies and their definitions, there's a need to facilitate the implementation of Felder and Silverman´s theories of learning styles by selecting the proper electronic media and teaching strategies for each style (Hong & Kinshuk, 2004), (Carver et al., 1999), (Felder & Silverman, 1988), (Gilbert & Han, 1999), (Paredes & Rodriguez, 2002).

The proposed taxonomy consists on matching the different learning styles with teaching strategies. It also suggests the suitable electronic media as a channel for its representation, thus personalizing it to every student. This taxonomy has been constructed based on our own diverse experiences with Soloman – Felder learning style theory and usage of e-media (Franzoni et al., 2008). It has been checked through an expert panel using the Delphi method which was held during the *III Congreso de Estilos de Aprendizaje* at Cáceres (Spain) in July 2008.

This taxonomy is based on the four learning styles dimensions (LSD):

$$LSD = \{LSD_1, LSD_2, LSD_3, LSD_4)\}$$

Each dimension is defined as a combination of four values according to the learning styles dimension (see table 2): LSD= {(Sensitive (**S**) / Intuitive (**I**)), (Visual (**Vi**) / Verbal (**Ve**)), (Active (**A**) / Reflexive (**Re**)), (Sequential (**Seq**) / Global (**G**))}.

In this case, there are 16 (2^4) learning styles combinations (LSC):

LSC={(S,Vi,A,Seq), (S,Vi,A,G), (S,Vi,R,Seq), (S,Vi,R,G), (S,Ve,A,Seq), (S,Ve,A,G), (S,Ve,R,Seq), (S,Ve,R,G), (I,Vi,A,Seq), (I,Vi,A,G), (I,Vi,R,Seq), (I,Vi,R,G), (I,Ve,A,Seq), (I,Ve,A,G), (I,Ve,R,Seq), (I,Ve,R,G)}.

A detailed review of the learning styles theory helped us establish the following three attributes for a learning style:

- description,
- appropriate pedagogical method
- characteristics of the media to the used

Then, the description and the appropriate method were associated to find the suitable teaching strategies, and finally the characteristics of media to be used mentioned in the learning styles theory was linked with the electronic media.

Each LSC can be associated with a teaching strategy (TS_i):

$$TS = \{TS_1, TS_2, \dots, TS_9\}.$$

Teaching strategies hold a one-to-many relationship with the learning styles. There can be one or many teaching strategies that accommodate one learning style.

Each LS can be associated with an appropriate electronic media (EM_i):

$$EM = \{EM_1, EM_2, \dots, EM_{27}\}.$$

Learning style hold a one-to-many relationship with the electronic media. For each learning style, there are one or many teaching strategies that can be implemented by one or many electronic media based on adequate learning style (see Figure 1).

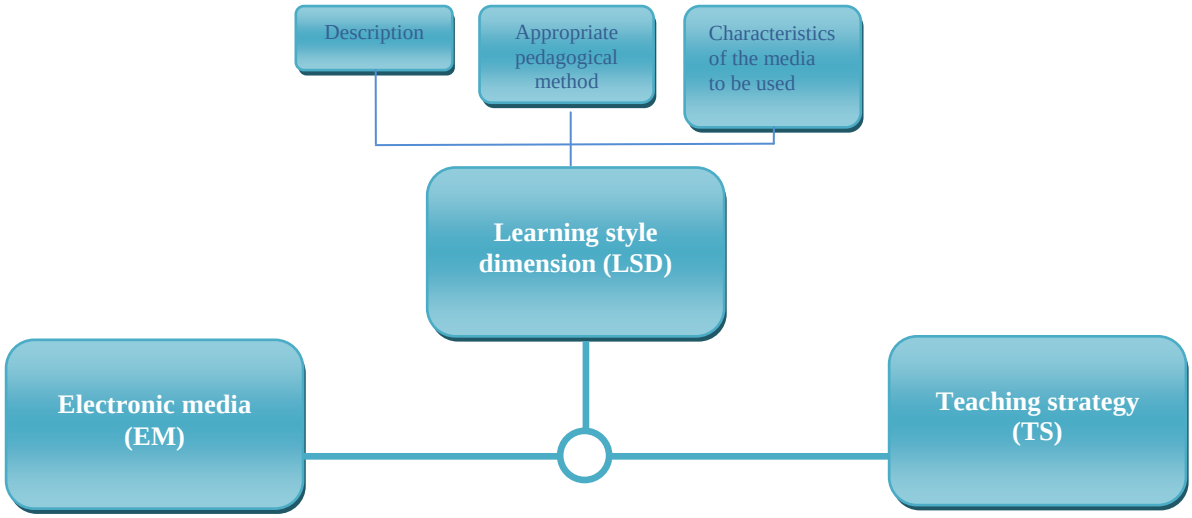

Figure 1. Adaptive Teaching Taxonomy relation entity diagram

For example, student with a sensitive style prefer practical content and methods that allow the solution of problems. When selecting the appropriate strategies, these must give priority to such practical work (learning based on problems, presentation and question and answer method). Electronic media, in turn, should contribute to these

priorities, animations, simulation and forums (among others), are examples of media that allow the implementation of pragmatic solutions that can also be based on problems.

Considering the intuitive style, as it prefers concepts, an exposition strategy is used, even though a discussion panel can also meet the requirements. On the other hand, considering that intuitive persons are innovators, a role playing session can also meet the objective. If we associate these with the electronic media, we find that student response systems, Internet research and webquest (among others), allow us to adapt these strategies. Tables 3, 4, 5 and 6 present in detail the adaptive teaching taxonomy for each learning style dimension. Integration elements for LSD_1 [Perception (Sensitive, Intuitive)] are shown on Table 3.

Table 3. Adaptive taxonomy for the LSD_1 [Perception (Sensitive, Intuitive)]

Perception / Specifications	**Sensitive**	**Intuitive**
Description	Practical. Don´t like courses without an immediate link to the real world	Conceptual, innovative, oriented to theory and meaning, enjoy working with abstract problems and mathematic formulations.
Appropriate pedagogical method	Specific, facts and procedure oriented, enjoy problem solving by following well established procedures, patient when dealing with details, enjoy practical work, lab class and can memorize things easily	Are innovative and hate repetitive work, rather discover possibilities and relationships, assimilate new concepts easily, don´t like courses that require much memory and tedious calculation.
Characteristics of the media to be used	Practical, problem solving oriented, laboratory and experiments	Theoretical, abstraction and math related
Associated Teaching Strategies	Presentation Question and answer method Learning based on problem solving	Discussion panel Games and simulations Role playing Case study Project design method

Integration elements for LSD_2 [Entry Channel (Visual, Verbal)] are shown on Table 4.

Table 4. Adaptive taxonomy for the LSD_2 [Entry Channel (Visual, Verbal)]

Entry Channel / Specifications	**Visual**	**Verbal**
Description	Highly visual elements	Oral and text elements
Appropriate pedagogical method	Rather work with visual representations when receiving information and remember what they see	Rather receive information spoken or verbally and remember what they read or hear
Characteristics of the media to be used	Visual representations and diagrams	Text and sounds
Associated Teaching Strategies	Games and simulations Presentation	Discussion panel Brainstorming Question and answer method

Integration elements for LSD_3 [Processing (Active, Reflexive)] are shown on Table 5.

Table 5. Adaptive taxonomy for the LSD_3 [Processing (Active, Reflexive)]

Processing / Specifications	**Active**	**Reflexive**
Description	Applicable and group work	Write short summaries
Appropriate	Tend to comprehend and assimilate new	Think about quietly before go ahead

pedagogical method	information when they practice using it (discussion, implementation, group presentations) and rather learn working with others	Stop periodically to review what have been learning Stop periodically to think possible questions Stop periodically to think possible applications
Characteristics of the media to be used	Group work and cooperation	Watching Listening
Associated Teaching Strategies	Games and simulations Learning based on problem solving Role playing Discussion panel Brainstorming Project design method	Presentation Case study Question and answer method

Integration elements for LSD_4 [Understanding (Sequential, Global)] are shown on Table 6.

Table 6. Adaptive taxonomy for the LSD_4 [Understanding (Sequential, Global)]

Understanding / Specifications	**Sequential**	**Global**
Description	Orderly, step by step and sequential	See everything as a whole
Appropriate pedagogical method	Learn through small orderly steps when these are logically associated and follow small orderly steps logically associated when solving problems	Learn through big leaps, suddenly and almost randomly, can solve complex problems quickly and put things together in an innovative way may have difficulties to explain how they did it
Characteristics of the media to be used	That allows content to be shown in steps (chapters)	That allow to see everything as a whole
Associated Teaching Strategies	Presentation Question and answer method	Role playing Brainstorming Case study Project design method

Table 7 show how can helping teachers, through knowledge of the ways our students learn to solve the problem of integrating new information technologies and configure new teaching and learning situations.

Knowing the learning styles of students we will select the type of teaching strategies (see table 7) and the most appropriate electronic media. (See table8)

Table 7. Adaptive taxonomy: LS dimensions and TS relationships

		Learning styles							
		Sensitive	Intuitive	Visual	Verbal	Active	Reflexive	Sequential	Global
Teaching strategy	Games and simulations		X	X		X			
	Learning based on problem solving	X				X			
	Role playing		X			X			X
	Presentation	X		X			X	X	
	Discussion panel		X		X	X			
	Brainstorming				X	X			X
	Case study		X				X		X
	Question and answer method	X			X		X	X	
	Project design method		X			X			X

According to teaching strategies selected in the table above the teacher can select the specific electronic media that should be the best appropriate to the instruct knowledge based on the learning style (see Table 8).

Table 8. Adaptive taxonomy: LS dimensions and EM relationships

			Learning styles							
			Sensitive	Intuitive	Visual	Verbal	Active	Reflexive	Sequential	Global
Electronic media	Audio	Audio Recording				X			X	
		Audioconference				X			X	
	Collaboration	Forums	X		X		X			X
		Online learning communities			X					X
		Weblog or blog	X				X			X
		Wikis	X		X		X			X
	Communication	Chat (Messenger)					X			X
		e-mail					X			X
	Diagrams	Animations	X		X					
		Graphics	X		X					
		Pictures	X		X					
		Simulations			X					
	Read	Digital magazines						X	X	
		Digital newspapers						X		
		eBooks			X			X	X	
		Hypertext (web pages)			X			X	X	
		Slideshows			X			X	X	
	Search	Internet research		X			X	X		X
	Tutoring	Course Legacy System		X						
		Student Response System						X		
		Tutorial systems		X				X		
		WebQuest		X				X		
	Video	Podcast				X				
		Recorded live events			X	X				
		Videoconference			X	X				
		Videos			X	X				
		Web seminars (broadcasts)								

Guidelines for use

The analysis of tables 7 and 8 should allow the teacher to determine the most appropriate teaching strategy and course material. Different approaches can be used. A recommendable approach consists in clustering students with similar learning styles and using the appropriate teaching strategy and material for each of the groups. Usually, the teacher is not able to implement such an approach, due for example to course time constraints, unavailability of the appropriate resources, etc. Should this be the case, another plausible approach consists of the identification of the "group average style" and the selection of the material accordingly. A third alternate approach (and perhaps the most recommendable one, should the resources allow it) consists of the use of different types of materials (thus targeting different styles) for a set of two or three learning units at a time. The selected material would be used on a rotational basis. This can be done with the integration of teams or groups of students having different learning styles. The adoption of this third approach allows the creation of team group skills for the students. Since the analysis of the table can result in having a list of suggestions (on teaching strategies to employ) that is still too long/complex to really serve as a guide for the teacher. In this situation the teacher might want to focus only on the teaching strategy that is representative of each category of learning style. This is illustrated in the following, overall recommendations are presented to select teaching strategy and prepare e-media material for each learning style.

Sensitive Learning Style: The content must be practical, courses must have an immediate connection with the real world, using concrete methods that are oriented towards facts and procedures that follow previously established techniques. The requested homework must be detailed, not global, including problem solving, laboratory exercises and concept memorization.

Teaching Strategy: Problem solving based learning.
Electronic Media: Forums

Intuitive Learning Style: The content must be innovative, oriented to theory and meanings, with abstractions and mathematical formulae, avoiding repetitive methods. The requested homework must include the discovery of relations and actions. The introduction of new concepts can be used but not as memorizing facts but as abstractions. Teaching Strategy: Discussion Panel
Electronic Media: Forums, Wikis, E-mail

Visual Learning Style: The content must be a heavy on visual components. The requested homework must include actions to visualize, the information gathering must use visual representations, images must be used in order to make it easier for the students to remember the contents, and the teacher can request diagrams that summarize the homework.

Teaching Strategy: Simulations and games
Electronic Media: Electronic Presentations, Videos (pedagogic), Animations

Verbal Learning Style: The content must have a lot of oral and textual components. The requested homework must include written essays or oral presentations, the information gathering must use textual representations, texts must be used in order to make it easier for the students to remember the contents, and the teacher can request abstracts that summarize the homework.

Teaching Strategy: Brainstorm
Electronic Media: Chats, blog, Forums

Active Learning Style: Students tend to comprehend and assimilate new information when they practice using it (discussion, implementation, group presentations) and rather learn working with others. The content must be applicable. The requested homework must include work in groups.

Teaching Strategy: Role playing
Electronic Media: Electronic Presentations, Digital Magazines, Digital Newspapers

Reflexive Learning Style: Students observe and ponder experiences. Data are collected and analyzed thoroughly about before any conclusion is made. The content must be related with experiences. The requested homework must include personal work.

Teaching Strategy: Cases study
Electronic Media: E-books

Sequential Learning Style: The content must be written orderly, step by step. The requested homework must consist of small orderly steps that are logically associated to the problems being solved. This allows content to be shown in steps (chapters).

Teaching Strategy: Presentation
Electronic Media: audioconference

Global Learning Style: The content must be written in big leaps, suddenly and almost randomly. Students can solve complex problems quickly and put things together in an innovative way but may have difficulties to explain how they did it. This allows seeing everything as a whole.

Teaching Strategy: Project design method
Electronic Media: Internet research

Application Method

The adaptive teaching taxonomy is a suggestion to change our way of teaching, student-centered, knowing the meaning and practical applications of the theory of learning styles. It's not that each of our actions conform to the

teaching styles of student learning. For applying the method in this example this would be impossible because of the diversity of styles found in the classroom. It is that throughout our classes offer a clear attention to the students of different learning styles, we organize activities that take into account individual learning style, that assessments are designed taking into account the variety of learning styles of students, by this way the student learning can guide properly.

The proposed method will link learning styles, teaching strategies and electronic media based on the adaptive taxonomy described above, according to a study plan or particular educational objectives to support teaching. There are three factors that affect the application method: teacher, student and the method itself.

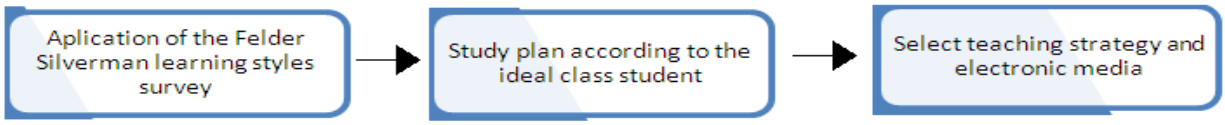

Figure 2. Phases for the application method

There are three main phases for this method (see Figure2):

- the application of the Felder and Silverman learning styles survey, when it's a traditional class, like the example shown in this article, as mentioned before, it is impossible to generate all the material in all styles of learning, therefore it is necessary to take into account the predominant styles of the students who will be the basis for the two examples selected targets of the material to cover,
- the study plan is reviewed to set the course objectives,
- selection of the teaching strategies and electronic media is according to the adaptive teaching taxonomy and based on the results of the learning styles questionnaire.

Not all the resulting teaching strategies and corresponding electronic media have to be used for every style. You can select the ones that are available.

Example of method application

The Instituto Tecnológico Autónomo de México´s (ITAM) Algorithms and Programs course (ID course - COM11101) for first year engineering students was used to test the validity of the method.

In the first phase the Felder and Silverman learning styles questionnaire was given to 26 students. The results are shown in Table 9.

Table 9. Results from the Felder Learning Styles Questionnaire

Dimension	Learning Style	Percentage of Students
LSD_1 Perception	Sensitive	62%
	Intuitive	38%
LSD_2 Entry Channel	Visual	85%
	Verbal	15%
LSD_3 Processing	Active	62%
	Reflexive	38%
LSD_4 Understanding	Sequential	62%
	Global	38%

The results show that in the Perception dimension, students are more sensible than intuitive. The most significant difference is in the Entry Channel dimension, where 85% students came out to be visual and only 15% were verbal. In the case Processing dimension, it was found that most of the students are active. Finally, in the Understanding dimension, it shows that they are mostly sequential. As a result, the predominant combination for each dimension style of the class is {(Sensitive/Visual/Active/Sequential)}.

In the second phase, the study plan is reviewed to specify the objectives of the course. The following information was used: The main objective of this prominently formative course is to develop within the student the ability to analyze and solve problems in a methodic way, as well as to express its solution in algorithmic terms. The student will get to know the basic techniques of procedural programming and will use them through C programming language.
This course is complemented with a two hour lab practice every other Friday. During this lab class the teacher will guide the students towards the solution of problems using "algorithms and programs".

Considering this course's characteristics, it is highly recommended that students solve the largest number of possible problems. Practice and application on specific problems of the concepts seen in class is what will allow a student to fully understand the theory.

These are the topics of the full course "Algorithms and Programs", which are arranged based in the specific objectives. Here are the different modules: 1. Course Presentation. 2. Algorithms, Programs and Flowcharts. 3. C Programming Language. 4. Modular Programming. 5. Unidimensional Array. 6. Bidimensional Array. 7. File and Character Chains. 8. Introduction to Structures. In this case, topic number 2 "Algorithms, Programs and Flowcharts" are the base for our example.

In this third phase, a selection of the teaching strategies and electronic media based on the adaptive teaching taxonomy is done according to the results of the learning styles questionnaire, and also based on the predominant style at this class {(Sensitive/Visual/Active/Sequential)}. Table 10 explain the description for each learning style selected, the appropriate pedagogical method, the characteristics of the media to be used, the teaching strategies and the fitting electronic media to be used for this particular style. The description give details about the preferences for the sensitive style, like must be practical, the material must be linked to the real world, with a highly visual approach and easily applicable; teamwork must be encouraged too, the teacher needs to consider all of this for create the course material. Tables 11 and 12 describe the example, how to consider this in the syllabus (Algorithms, Programs and Flowcharts topic).

Table 10. Representative student adaptive learning taxonomy {(Sensitive/Visual/Active/Sequential)}

Perception / **Specifications**	**Sensitive**	**Visual**	**Active**	**Sequential**
Description	Practical. Don´t like courses without an immediate link to the real world	Highly visual elements	Applicable and group work	Orderly, step by step and sequential
Appropriate pedagogical method	Specific, facts and procedure oriented, enjoy problem solving by following well established procedures, patient when dealing with details, enjoy practical work, lab class and can memorize things easily	Rather work with visual representations when receiving information and remember what they see	Tend to comprehend and assimilate new information when they practice using it (discussion, implementation, group presentations) and rather learn working with others	Learn through small orderly steps when these are logically associated and follow small orderly steps logically associated when solving problems
Characteristics of the media to be used	Practical, problem solving, laboratory and experiments	Visual representations and diagrams	Group work and cooperation	That allows content to be shown in steps (chapters)
Teaching Strategies	Presentation Question and answer method Learning based on problem solving	Games and simulations Presentation	Games and simulations Learning based on problem solving Role playing Discussion panel Brainstorming Project design	Presentation Question and answer method

			method	
Electronic Media	Collaboration Diagrams	Collaboration Diagrams Read Video	Collaboration Communication Search	Audio Read

According to electronic media categories selected in the table above the teacher can select the specific electronic media that should be the best appropriate to instruct knowledge (see Table 8).

Table 11. Using adaptive taxonomy for algorithms topic

Specific Objective	Content	Teaching Strategies	Electronic Media
1. Identify places where algorithms will be used.	- Set examples using algorithms.	*Learning based on problem solving *Brainstorming	Communication(chats, email), Collaboration (forums, wikis)
2. Define Algorithms.	- Define algorithms using previous examples - Establish problems to be solved using algorithms	* Role playing * Question and answer method * Discussion panel	Collaboration (forums, wikis) Internet research
3.Solve simple problems using algorithms.	- Solve a problem using algorithms	* Learning based on problem solving	Diagrams(animations, graphics, pictures)

Table 12. Using adaptive taxonomy for flowcharts topic

Specific Objective	Content	Teaching Strategies	Electronic Media
1. Define flowcharts.	- Associate the concept of algorithm with diagrams or sketches	* Presentation	Audio(audio recording, audio conference)
2. Compare algorithms with flowcharts.	- Identify the pros of solving problems using flowcharts. - Establish the importance of using diagrams to help solving more complex problems.	* Presentation *Question and answer method	Read(eBooks, hypertext (web pages), slideshows)

The different ways of doing the course helps in raising the learning abilities of the student. The teacher displays the information in different ways, with different resources, making the learning process easier due to the fact that some people are more receptive to some kind of information than the others. The previous table displays the wide variety of resources that the teacher might use (if available), according to the course objectives. It is also helpful to identify and select the different tools that might be used. Examination of the table allows the teacher to get a better knowledge of the different potentially useful tools, as well. This can result in a better integration of strategies and selection of instructional tools (some of which might be unknown by the teacher) in later courses. The results of the students were better than other courses which did not use our method. The student's evaluation of the course was much better as well. The use of several resources helps all kinds of students; they were globally very satisfied with the electronic media used. The method was accepted positively by the students. They thought that this is an innovative idea that can help people have a better performance whilst learning.

There are many studies concerning learning styles and their usage in teaching methods, and there are many tutoring systems without a pedagogical method (Gilbert et al., 2005). This adaptive teaching taxonomy presented here is different because it deals directly with the problem of matching teaching strategies with electronic media based on learning styles. Even though the presented example is a traditional class (face to face), it can be completely automated if the discussed set of rules is applied. This way, if an e-learning system is implemented, full personalization of the learning process may be achieved.

Conclusions

The work presented in this paper describes the development of an integrated taxonomy combining learning styles, different teaching strategies and the corresponding appropriate electronic media. The objective is to provide a structured method to help in facilitating the learning process and personalizing the pedagogical resources. This method can be used in traditional face to face classes where the teacher can calculate the course's student's representative learning style to choose the suitable media as proposed by the adaptive teaching taxonomy. It can also be used in distance learning courses where it acts like a catalyst to achieve an automatic personalization in the hypermedia systems. It is worth mentioning that combining teaching strategies with electronic media as proposed by our method doesn't act in an excluding way. It can be combined with any additional teaching approach and/or teaching resources. Because the method and the adaptive taxonomy are user friendly, the person implementing this method doesn't have to be information technology subject matter expert.

We consider the recommendations on teaching strategies and electronic media that match a certain learning style as an important contribution to the field of pedagogical teaching methods. The evaluation of student's learning style gives a strong insight about the students' ability to capture the teacher's message. The proposed taxonomy offers a wide range of possibilities for building a course. Even if full personalization is not possible in face to face teaching, the teacher can develop different versions of the teaching material so that to fit to the learning styles of the largest number of students. It might happen that a teacher does not know the students' learning styles. Furthermore, he/she might not know either the appropriate educational strategies or instructional material for their courses. The presented taxonomy is thus a useful tool to get a better knowledge of the wide variety of resources available to use in class.

A two phase evaluation of the method to test its efficiency is actually under investigation. The first phase will deal with available off the shelf educational software, and the second phase will be in a suited system under implementation at the ITAM. The objective is to test full personalization of the learning process and to validate the adaptive taxonomy in a quantitative based research approach. Another direction of research is to test the adaptive taxonomy in different knowledge domains. We tend to believe that for a given learning style, some strategies and electronic media apply differently when teaching different domains. Specific adaptive taxonomy combinations can be found to be more useful for certain knowledge domains like linguistics, programming or physics for example.

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