Individualizing tutoring with learning style based feedback

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Abstract: In open-structured domains such as object-oriented design, feedback cannot be standardized error messages or the solution to the problem. To attain the success of effective human tutors, these systems should adapt to a student's learning style. We introduce a pedagogical framework that incorporates the Felder-Silverman learning style model and their validated instrument for assessing individual learning style. The framework provides a feedback infrastructure based on the learning style model dimensions (such as visual, verbal, intuitive, sensor, etc.). It has been implemented as part of the DesignFirst-ITS, helping novices learn how to design a class in UML from a problem description. The system has been evaluated in a CS1 class with results that show that students found the learning-styles based feedback effective in helping them identify and correct errors so that all were able to complete a non-trivial problem.

1. Introduction

Intelligent tutoring systems (ITS) have proven to be a useful tool in providing learning support to individual learners. ITSs typically adapt to individual students by identifying gaps in their knowledge and presenting them with feedback to fill in these gaps. Even though ITS are quite successful in helping students learn, they still fall short of what effective human tutors can do: they also present information in a form that is customized for each student, taking into account individual characteristics and preferences, while individualizing both the tutoring content and process. The individual characteristics and preferences of the student are dubbed individual learning style. For the ITSs to match the success of good human tutors, they need to adapt not only to the knowledge level but also to the learning style of the student to maximize learning.

Learning style refers to individual skills and preferences that affect how a student perceives, gathers, and processes learning materials [14]. Research has shown that people learn more when the instruction is matched to their individual learning styles [4, 6]. As a result, a number of adaptive educational systems have been developed that are based on learning style research: CS383 [3], Arthur [13], iWeaver [31], EDUCE [15]. These systems integrate learning style research by maintaining a learning style profile for each student and using this profile to adapt the presentation and navigation of instructional content to each student. These systems do not use learning styles to adapt feedback interactively.

Developing e-learning systems that adapt to student learning styles is not a trivial task. Design and development challenges include selecting the appropriate learning style model and instrument, creating course content consistent with the various learning styles, and determining the level and degree of adaptation of domain content. It is even more challenging to design an ITS that adapts to individual learning style because the ITS focus more on student interpretation and understanding of the domain knowledge rather just the presentation mode and delivery of it as in adaptive hypermedia systems.

This paper presents a pedagogical framework that generates multidimensional feedback that is not only based on the knowledge level of the student but also on the individual learning style of the student. This pedagogical framework is based on the Felder-

Silverman learning style model and is implemented in DesignFirst-ITS (formerly known as CIMEL-ITS [references]), an ITS to help novices learn how to design classes, methods and attributes to solve a problem.

The rest of this paper is organized as follows: section 2 describes related work; section 3 gives a brief overview of Felder-Silverman learning style model; section 4 describes the pedagogical framework; section 5 describes the DesignFirst-ITS; section 6 describes evaluation results; and section 7 presents the conclusion and future work.

2. Related Work

Learning style research became very active in the 1970's and has resulted in over 71 different learning style models and theories. Some of the most cited theories are Myers-Briggs Type Indicator [23], Kolb's learning style theory [17], Gardner's Multiple Intelligences Theory [11] and Felder-Silverman Learning Style Theory [7, 8]. Learning style research has been used in various settings and at different levels. In industry, corporations are using learning style research to create supportive work environments that foster communication and productivity. In academia, learning style research is being used for different purposes: to provide learning support to K-12 children who are either struggling or are gifted; to help college students maximize their learning gain by providing them insight into how they learn; and to help instructors design courses that appeal to students of various learning styles.

Learning style is also being integrated in adaptive e-learning environments with many designers creating systems based on learning style research. Adaptive e-learning systems are ideal for creating learning style based instructional material as they do not face the same limitations as human instructors who are unable to cater to individual students due to lack of resources [14]. Some of the adaptive systems that incorporate learning style are CS383 [3], ACE [25] , AES-CS [27] and Flexi-OLM[18].

All these systems are based on different learning style models and use different methods to obtain the learning style of the user. One method is to have the user fill out a learning style questionnaire which usually accompanies the learning style model on which the system is based. Another method is to infer the student preferences from his interaction with the system, such as the pages the student visits and the links that he follows. After obtaining the student learning style, these systems use that information to adapt the sequence and/or presentation form of the instructional material to the student.

CSC383 [2] an AEHS for a computer systems course (CSC383) modifies content presentation using the Felder-Silverman learning style model. Learners fill out the Index of Learning Style questionnaire (ILS) that categorizes them as sensing/intuitive, verbal/visual and sequential/global. For example sensing learners like facts while intuitive learners like concepts, visual learners like pictures / graphic while verbal like written explanations and sequential like step by step while global learners like to see the big picture first. CSC383 matches the presentation form of the content to match the students learning style. For example, visual students are presented information in the graphical form while the verbal students receive the information in text form, etc.

The Flexi-OLM system models a learner's understanding of basic C programming based on their answers to multiple-choice and short-answer questions. The system supports a open learn model and enables the learner to view information about their skill level, knowledge and misconceptions in a choice of seven formats, designed according to Felder and Silverman learning style model.

Formal and informal evaluation studies of CSC383, ACE and AES-CS suggest that students learn more when the system adapts to individual learning style. Not all adaptive systems that incorporate learning style support the hypothesis that learning style adaptation results in increased gains. For example, evaluation studies of EDUCE [15] suggest that students learn more when they receive instruction that is mismatched to their learning style. One reason for these inconsistent evaluation results is that different systems are based on different learning style models and all these models have a different perspective of what individual characteristics affect the learning process. Another reason is that there are no set guidelines or standards designers can use to create learning style based systems. Lack of standard methodologies also makes it difficult to determine the effectiveness of these systems. Yet another reason could be that some adaptive hypermedia systems use learner navigation data to keep an updated learning style profile of the learner and the learners do not necessarily only browse the information format that would be considered the best match for their learning style.

3. Felder-Silverman Learning Style Model

The Felder-Silverman Learning Style Model [7] categorizes a student's learning style on a sliding scale of four dimensions: *sensing-intuitive, visual-verbal, active-reflective* and *sequential-global.* Table 1 summarizes learning environment preferences of typical learners from each of the four dimensions of the Felder-Silverman model.

Active	Tries things out, works within a group, discusses and explains to others
Reflective	Thinks before doing something, works alone
Sensing	Learns from and memorizes facts, solves problems by well-established methods, patient with details, works slower
Intuitive	Discovers possibilities and relationships, innovative, easily grasp new concepts, abstractions and mathematical formulation, works faster
Visual	Learns from pictures, diagrams, flow charts, time lines, films, multimedia content and demonstrations
Verbal	Learns form written and spoken explanations
Sequential	Learns and thinks in linear/sequential steps
Global	Learns in large leaps, absorbing material almost randomly

The Index of Learning Styles (ILS) instrument supports the Felder-Silverman learning style model by categorizing individual learning style preferences along different dimensions of the model [11]. The ILS is a questionnaire containing 44 questions, 11 questions corresponding to each of the four dimensions of the learning style model. Each question is designed to determine if a respondent tends to belong to one category or another on that dimension. It does so by asking the respondent to choose only one of two options where each option represents each category. Since there are 11 questions for each dimension, a respondent is always classifiable along each dimension. The range of data for each dimension is from 0 to 11. Since there are four dimensions and each dimension has two poles there are 16 possible combinations, i.e. types of learner, in this model. The learning style dimensions of this model are continuous and not discrete categories. This means that the learner's preference on a given scale does not necessarily belong to only one of the poles. It may be strong, mild, or almost non-existent.

The Felder-Silverman learning style model was chosen for several reasons: its ease of use, the Index of Learning Styles which has been validated and provides a convenient way to assess student learning style [10, 19, 32, 28]; limited number of dimensions of the model make it easier to incorporate it into an educational system; it has been used by educators at various institutions to help improve education [7, 26]; many Adaptive Hypermedia Systems such as CS383 [3] TANGOW [24] and WHURLE [2] use this model to adapt the course presentation / sequence to individual learners.

4. Pedagogical Framework

Our pedagogical framework is designed to provide feedback that addresses multiple dimensions of the Felder-Silverman model. This framework consists of two components: a feedback infrastructure that contains the feedback components and an algorithm that dynamically chooses these components to create coherent feedback based on students' learning style and students' erroneous action. These components contain information in the form that is suitable for learners that have a preference for various dimensions of the model. This pedagogical framework supports multiple levels of feedback, the first level being a gentle reminder and last level being detail explanation of the concept. This multiple hint strategy is called "hint sequencing" [12] and it refers to a sequence of hint templates that are used to generate feedback. The first hint is usually very general and as the student continues to need help about a given concept, the hints keep on getting more and more specific. Many of the successful tutors such as PAT [16] the Algebra tutor, and LISPITS [5] a tutor for LISP use this strategy. This strategy is also used by successful human tutors who offer multiple levels of feedback, they tend to start with a general hint and proceed to more specific hints related to students' erroneous actions [21].

Unlike other systems, our system does not end up providing the solution (since a design does not have one solution), but instead offers more help in the form of a tutorial. The tutorial mode walks a student through a detailed explanation of the concept with examples. The tutorial mode can also help students who just want to learn a concept before working on their solution.

The student learning style information is obtained using the Index of Learning Style instrument (ILS) [9] which the students fill out prior to using the system for the first time.

4.1 Feedback infrastructure

The feedback architecture consists of the following components that contain information in the form that is suitable for different dimensions of the Felder-Silverman learning style model.

1. **Definition** – This component contains definitions of domain concepts and will be used while introducing a concept. This particular component is useful for many learning style dimensions such as verbal, sensor, intuitive. An example of this

component would be "Attributes are characteristics of an object that persist through the life of that object." This component does not apply to the global / sequential dimension of learning style.

2. **Example** – This component contains examples that illustrate a given concept. It can be used for almost any learning style, especially the sensor style which prefers a practical approach to concepts. An example of feedback in this component might be "Attributes of a car might be its color, model, make, etc."
3. **Question** – This component contains questions that could serve as hints during the interactive mode. There are two different types of questions: closed-ended questions that require a learner to simply answer yes/no or just provide a factual answer, and open-ended questions that require a student to think about his problem solving behavior. This component is very important in making the learner think about his problem solving action. This is very important for a "reflective" type learner as it gently nudges him to reflect on his action. It can also be useful for intuitive, global, and sequential learners as the open ended questions can lead to them to think about the relationships between different steps/things, about the big picture and about the steps involved in creating the solution. An example of a closed-ended question in this component might be "Is the correct data type to represent money a double?" and an example of open-ended question would be "Why did you set the data type for money to string?" Open-ended questions encourage the student to reflect about her reasoning process.
4. **Scaffold** – This component comes in handy to nudge a learner who might be lost towards a correct solution and point him in the right direction. Often it is not enough to tell a novice that his action is incorrect but one should also guide him as where to go for to find the right answer. An example of this component would be something like "Use the tutorial to learn about 'passing data to a method'." This component is useful for global, intuitive, and sensor learners.
5. **Picture** – This component contains picture, image, multimedia, animation, or video and is very much for the "visual" learner. It contains images and pictures that visually explain a concept. For example when teaching the concept of data type, one could create an image consisting of transparent containers marked as int, long, double, String, etc. These containers could have things such as a dollar sign in the double container, age in the int container, name in the string container, etc. This component is also useful for global learners as it allows them to view the big picture.
6. **Relationships** –This component contains information that helps a learner understand how a concept fits in to the overall problem solving activity. Often learners understand a concept but have a difficult time understanding how it fits into the context of the problem. For example, a student might understand what attributes and methods are but might not know the relationship between the two in the context of the problem. This component is mainly useful for "global" learners who like to know the big picture first.
7. **Application** – This component contains information about a concept that extends beyond the concept definition and is useful in the application of the concept. For example, a student might know the definition of a constructor but might not know that a class could have multiple constructors. This component is mostly suitable for sensor learners.

Each of these components has the following attributes that are used by the assembly algorithm to create feedback that is presented to the student.

Concept: unique concept in curriculum associated with student's error [30]
Related_concept: relationship concept that student may not understand [30]
Level: use this component for which of three levels of feedback
Type: component feedback type (definition, question, etc.)
Category: component dimension (visual/verbal, active/ reflective, etc.)
Content: actual text or name of the visual / animation file
usability_factor: how often this component has been used
Compatible_components: others that can be used with this component
Presentation_mode = verbal / visual

4.2 Assembly algorithm

The assembly algorithm uses the feedback infrastructure, student feedback history, learning style profile, student model information, student problem solving action and assembly rules to generate appropriate feedback for the student. The student feedback history contains all the feedback that the student has received for each concept in the past. The learning style profile specifies the preferred learning style of the student such as active/reflective, sensor/intuitive, sequential/global or verbal/visual. The student model contains information about how well the student understands each concept. The current student problem solving action provides the system with the concept for which the student needs feedback.

Assembly rules are used to ensure that the feedback that is being generated is coherent and makes sense. These rules dictate which components can be used together and which transition words should be used to connect these components. For example, one of the assembly rules dictates that two definition components should not be used together for the same concept. Another assembly rule, responding to confusion about a relationship concept [30], dictates that if providing feedback for two different concepts, use the same type of components for each concept. Suppose a student is confused between the concepts "attribute" and "parameter" and the student needs feedback about both concepts. Instead of providing definitions of each concept, it would make more sense to give an explanation about the relationship and an example of each concept.

Generating learning style based feedback is a complex task since it requires that the feedback must address the knowledge gap of the student and it must also be in sync with the student's learning preference. Beyond the content, presentation of feedback also impacts its effectiveness. The Felder-Silverman learning style model addresses multiple aspects of learning through it dimensions.

Our pedagogical framework uses the verbal / visual dimension to individualize the presentation style. Learners preferring the verbal category receive feedback that is in the form of written words while visual learners also receive feedback emphasizing images, pictures and multimedia. The active / reflective dimension distinguishes between active learners, who prefer hands-on activity and receive interactive content, and reflective learners, who are presented with open-ended questions. The sequential / global dimension o determines if the learner prefers feedback on the given concept itself or other information about how this concept relates other concepts. The intuitive / sensor dimension determines whether to explain the concept abstractly or with concrete facts.

The system maintains a cross reference of dimensions of the Felder-Silverman model and components in the feedback infra-structure. The system uses this cross reference to choose components to generate learning style based feedback. The system also specifies how much information to provide for each feedback level.

5. DesignFirst-ITS

DesignFirst-ITS is an intelligent tutoring system that provides one-on-one tutoring to help beginners in a CS1 course learn object-oriented analysis and design, using elements of UML [1]. DesignFirst-ITS is based on a "design-first" curriculum that teaches students to design a solution and the objects that comprise it before coding [22]. This curriculum enables students to understand and comprehend the problem without getting bogged down with programming language syntax.

The Curriculum Information Network (CIN) consists of domain knowledge which is object-oriented design concepts. These concepts are linked together through various relationships such as prerequisite and equivalence and assigned a measure of learning difficulty. For example, Prerequisite (class: object) shows that the concept "object" is a prerequisite of "class". In other words, the student must understand what an object is before he can create a class.

The Expert Evaluator (EE) interfaces with a student through the LehighUML plug-in, created for the Eclipse Integrated Development Environment (IDE). Eclipse IDE is a Java development environment that can be extended by integrating plug-ins (software modules) to provide additional functionality. The LehighUML plug-in allows the student to create UML class diagrams. As the student designs a solution for a given problem in the plug-in environment, it reports each student action in a database on a server. The EE evaluates each of the student's steps in the background by comparing it with its own solution and generates an information packet for a correct student action and an error packet for an incorrect action. The Student Model (SM) finds these packets in another database table. The SM analyzes these packets to determine the knowledge level of the student for each concept and attempts to find reasons for student errors [17]. The SM uses this information to update the student model and passes the original packets along with the reason packet to the pedagogical advisor (PA).

The PA is based on the learning style based pedagogical infrastructure described above. Taking into account the curriculum information network (CIN), the EE analysis of the student's actions and the SM analysis of the student's understanding of concepts in the CIN, the PA determines what feedback to provide to the student.

6. Evaluation

A beta version of DesignFirst-ITS (with just the hint level of feedback) was evaluated in two introductory computer science courses with a total of 33 students at Lehigh University. The goal of the evaluation was to determine if the students were able to understand the ITS feedback and if they found it helpful. The students filled out the Index of Learning Style (ILS) questionnaire, which the PA of DesignFirst-ITS used. The students learned the basic concepts of objects and classes and how to manipulate them in the Eclipse environment through a multimedia lesson. Then an instructor explained a step-by-step procedure for creating an object-oriented design solution based on a problem description in English to generate the primary class, its attributes, and methods. As an assignment, the students were given a problem description of a movie ticket vending machine. The students followed the procedure to generate a solution from the problem description and to create a class diagram using the LehighUML plug-in and the DesignFirst-ITS.

The students logged into DesignFirst-ITS and started to input their design in the LehighUML plug-in. As the students worked on their design in the plug-in, they received feedback from the ITS anytime they made an error. The students who showed strong preference for the visual dimension of the Felder-Silverman model received feedback in the forms of images and diagrams while students with strong preference for verbal dimension received feedback in the form of words.

All of the students completed the problem solution (non-trivial for novices). After finishing, they were given a PA evaluation questionnaire that asked them specific questions about the feedback that they received from the ITS. The intent of this questionnaire was to determine how the students reacted to the PA and if they found the feedback helpful in identifying the errors and also helped them in fixing these errors. Other reasons were to determine if the students liked the visual feedback and actually understood the information conveyed in the images / diagrams. 32 questionnaires were returned. Out of 32 students, 23 received visual feedback because their preferred learning style was visual while only 9 students received text only feedback because their preferred learning style was verbal. 20 students found ITS advice helpful in identifying their errors while 14 found it helpful in helping them in correcting their error. 16 students out of 23 liked the visual feedback with images and 17 students understood the feedback contained in the images. Finally, 23 students both visual and verbal liked the pedagogical advice.

This spring, we have begun a study that examines the performance of the complete PA, with all four dimensions of feedback and the tutorial mode, with students participating in the Launch-IT outreach project (www.lehigh.edu/launchit). An experimental group saw feedback based on their own learning style while a control group saw generic, text-based feedback. . All students took a pretest and posttest before and after the students completed their assignment. The preliminary results show a significant improvement for all students using the tutoring system (mean of 4.6 out of 13 questions, t=.001). For the PA, there was a significantly higher gain for students using the experimental group (mean gain of 4.5, t=.001) and a difference between gain for experimental and control groups (mean of 1.0, t=?). We will be gathering and analyzing more data before the workshop.

7. Conclusion and Future Work

We have described a general framework for providing pedagogical advice tailored to individual learning style, determined with a well-established learning style model and a validated instrument. We have specified the overall architecture and assembly algorithm and implemented a pedagogical advisor that provides the hints level of feedback. Evaluation results indicate that this advice is effective at helping student identify their errors (by connecting them with relevant concepts in the curriculum), and students agree.

The pedagogical framework will also contain a graphical user interface for an instructor to input additional learning style based feedback into the system. The goal is provide a generic framework that instructors can use to develop other open-structured systems.

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