Learning styles in an e-learning tool

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***Abstract* - As Computer Science teachers we are sensitive to the difficulties felt by our students, especially those related with initial programming learning. This global problem has motivated several authors to investigate its causes and to propose several approaches and tools to help students. However, drop out and failure rates in programming courses are still remarkably high in many institutions. We believe that many courses could take advantage of a planned and concerted e-learning or b-learning strategy. This strategy should be supported by an e-learning tool that provides a set of suitable activities, according to each student's cognitive needs and knowledge level. In this paper we describe some models that have been proposed to classify students learning styles. We also suggest programming learning activities suitable to support each learning style. Those activities will be included in an educational environment currently under development.**

Index terms - Computer Science Education, E-learning, Learning styles, Programming learning

INTRODUCTION

The utilization of technology supported contexts can bring a new and more flexible approach of teaching and learning to Education. This new paradigm can be used to create teaching and learning models focused on the individual student.

Although most courses can take advantage of a planned and concerted strategy of e-learning or b-learning, as Computer Science teachers we are mostly sensitive to the difficulties that many of our students feel, especially those related with programming learning.

A lot of novice students show difficulties to organize ideas and define the necessary actions to solve a particular problem. Many of them don't understand and don't know how to apply abstract programming concepts, like control structures, to create algorithms that solve concrete problems.

The high failure rates reported in initial programming courses worldwide motivated several authors to investigate the causes of such difficulties [1-3]. Several pedagogical approaches and tools were proposed to help students learn to program. Many of those tools are based on animation and visualization of algorithms and programs. Although some positive effects were reported after the utilization of some tools [4-5], the number of students that drop out or fail programming courses is still remarkably high.

Programming is essentially a problem solving activity that needs a lot of practice from the students. In our opinion, learning to program cannot be achieved by reading books and assisting lectures. It is fundamental that students solve programming problems and learn from that. Even errors can be learning opportunities, if the student is able to locate, understand and correct them.

We think that an easily available computer-based tool could be very useful to support each student autonomous work. To be effective it must integrate a set of activities adapted to the student needs in each learning stage. This type of computer-based environment should guide each student through an individual set of activities, in accordance with her/his knowledge level. Students can perform their tasks according to their own rhythm and reasoning, without anybody observing them and at their own pace.

However, to be fully adapted to each student, the environment must take into consideration not only the student current knowledge level, but also her/his learning style. People learn in several ways and have different preferences to approach new materials. For example, some individuals prefer to learn in a team, while others work better alone. Some tend to prefer more practical activities and others like to learn by reading and reflecting about the subject. To be effective the environment must support individual learning preferences and be able to present activities adequate to each student.

LEARNING STYLES MODELS

Several authors have proposed different definitions for learning style. For example, in [6] learning style is described as an expression of individuality, including qualities, activities, or behavior sustained over a period of time. In educational psychology, style has been identified and recognized as a key construct for describing individual differences in the context of learning. According to [6], key elements in this construct consist of one's affect (mood, feelings), behavior (doing things, activity), and cognition (thinking and knowing). This author reinforce that each person's personal style is the way in which that individual systematically and habitually responds to and works on a learning task.

Keefe [7] defines learning styles as "cognitive characteristics, affective and psychological behaviors that serve as relatively stable indicators of how learners perceive, interact with and respond to the learning environment".

Several learning style models were proposed aiming to classify and characterize how students receive and process information. They basically refer to two fundamental aspects of a learner's personal style, namely her/his cognitive style, the way she/he thinks, and her/his learning strategy, the processes she/he uses in response to a learning task. Some well known models are those proposed by Myers-Briggs, Kolb and Felder-Silverman, which will be briefly described in the next sections

I. Myers-Briggs Model

The Myers-Briggs model [8] was developed by Isabel Briggs and Katherine Briggs to classify types of personality. It is based on Carl Jung's Theory of Psychological Types [9] and provides a multidimensional approach to personality types and learning styles. The instrument used in this model is called Myers-Briggs Type Indicator – MBTI. It uses four bipolar pairs to describe the individual and yield to 16 different personality types with concomitant learning style differences. Each of the bipolar pairs is described below. Despite this model be primarily used to classify the student's personality, it is also employed to measure his/her learning style, since the scales it defines are based on cognitive concepts.

- **Extraverts/Introverts**. This dimension measures the way in which the learner gets energy. Some get energy from people, while others get energy internally through thinking. The continuum ranges from extreme extraversion where the learner cannot function except in interaction with others, to extreme introversion where the learner would like to be alone. Extraverts are individuals who generally focus on the outer world. They like to experiment things and interact with other persons in their learning group. On the other hand, the introverts concentrate in their own world and prefer to work alone;
- **Sensory/Intuitive**. This dimension describes individuals' preferences for ways of finding out about things. The extreme sensor wants to find out by observing or using the senses to find things out. The extreme intuitive looks for meaning by seeing new possibilities which relate to potential meaning and perceived relationships. Sensors are practical, attentive to details and, in general, stick to the facts. Intuitive are innovative, like abstract concepts, and concentrate on possibilities and concepts;
- **Thinkers/Feelers**. This dimension relates to preferences in terms of the ways in which individuals make decisions. Some decide based on logical and rational processes and others based on how they feel. An extreme thinker will only make rational decisions after a logical analysis of the question or problem. On the other hand, an extreme feeler decides quickly, based on the feeling the decision generates at the moment. Thinkers like to make decisions based on rules and reason, generally are creative and have ability to solve problems. The Feelers are more contemplatives and tend to make decisions based on personal feelings;
- **Judgers/Perceivers**. This dimension deals with the way individuals view the world. Perceivers view the world using perceptive processes. Extreme perceivers live spontaneously and are very flexible. Judgers use a judging process and in the extreme live in a very orderly and planned way. Judgers like to plan and follow agendas, whereas perceivers tend to have facility to adapt to changing circumstances.

By combining these four categories it is possible to have up to 16 types. For instance, a student ESTJ would be extravert, sensory, thinker and judger. In spite of the Myers-Briggs model being primarily used to classify the student's personality, it is also employed to measure learning styles, since many categories are based on cognitive concepts. It is worthy noting that all sort of personalities are useful in the engineering field. Naturally, the ideal case would be one where the teacher creates a heterogeneous environment that favors all kinds of students.

II. Kolb's Experiential Learning Model

Kolb developed the Learning Style Inventory (LSI) to evaluate the way people learn and work with ideas [10]. This instrument consists of twelve questions in which the subject selects one of four possible responses.

The four possible choices in the instrument relate to the four stages Kolb identified as a cycle of learning: Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC) and Active Experimentation (AE). He paired AE and RO as polar opposites (doing vs. watching) and CE and AC as polar opposites (feeling vs. thinking). Concrete Experience (CE) emphasizes active involvement, relating with other people, and learning by concrete experiences (like seeing, listening and feeling). Learners in the CE phase are open-minded, adaptable, and sensitive to their feelings and other people's feeeling. In Reflective Observation (RO), the next stage, the learner watches and listens, views issues from different points of view, and discovers meaning in the learning material. Abstract Conceptualization (AC) is the application of thought and logic, as opposed to feelings, to the learning situation. Planning, developing theories, and analysis are part of this third stage. The last stage is Active Experimentation (AE) and involves testing theories, carrying out plans, and influencing people and events through activity. A complete cycle of learning involves each of these stages.

The Kolb's model can be summarized in the following two dimensions, according to the student's preferences:

- Information perception – refers to the perception channels. Individuals can be more apt to Concrete Experiences (to see, to listen, to touch, etc.) or to Abstract Concepts (the use of mental or visual concepts);
- Information processing – refers to the way the information is processed. Individuals can be more comfortable with reflexive observation (to think about the things) or active experimentation (making something with the information).

The instrument developed by David Kolb – the Learning Style Inventory – LSI, takes into account the two dimensions described above and classifies the students in four different categories:

- **Diverger** (concrete and reflexive) – The predominant characteristics of this style are the EC and OR. These individuals are able to look at things from different perspectives. They prefer to observe rather than to do. They like to process the information by reflection and they are better in concrete circumstances;
- **Assimilator** (abstract and reflexive) – The predominant characteristics are CA and OR. These people perceive information through mental models and process it in a reflexive way. They are theorists and require good clear explanation rather than practical opportunity. They are called assimilators because they analyze, organize, and assimilate pieces of information with great facility.
- **Converger** (abstract and active) – The predominant characteristics are CA and EA. These persons are fast to make decisions, have ability to solve problems and use their learning to find solutions to practical issues. They prefer technical tasks and are less concerned about people and interpersonal aspects;
- **Accomodator** (concrete, active) – The predominant characteristics are EC and EA. They rely on intuition than logic. They like to work in team and prefer to take a practical and experiential learning. Generally they try different ways to achieve an objective.

III. Felder–Silverman Model

In 1988, Richard Felder and Linda Silverman developed a learning model [11] that focuses specifically on aspects of learning styles of engineering students. Three years later, a corresponding psychometric assessment instrument, the Felder-Solomon's Index of Learning Styles, was developed.

Their model permits classify students in five categories, Sensory/Intuitive, Visual/Verbal, Active/Reflective, Sequential/Global, Inductive/ Deductive. The dimensions Sensory/Intuitive and Visual/Verbal refer to the mechanisms of perceiving information. The dimensions Active/Reflective and Sequential/Global are concerned with processing and transforming information in understanding.

- **Sensory/Intuitive** – Sensory learners tend to like learning facts; intuitive learners often prefer discovering possibilities and relationships. Sensors often like solving problems by well-established methods and dislike complications and surprises; intuitive learners like innovation and dislike repetition. Sensors tend to be patient with details and good at memorizing facts; intuitors may be better at grasping new concepts and are often more comfortable than sensors with abstractions and mathematical formulations. Sensors tend to be more practical and careful than intuitors. This dimension has some similarities with the categories Sensory/Intuitive of Myers-Briggs Model.
- **Visual/Verbal** – Visual learners remember best what they see - pictures, diagrams, symbols, flowcharts, timelines, films and demonstrations. If something is simply said to them they will probably forget it. Verbal learners get more out of words - written and spoken explanations. They get a lot of information about what they heard and more of what they heard and they said. They learn a lot with discussions, they prefer verbal explanations to visual demonstrations, and learn effectively by explaining things to others.
- **Active/Reflective** –Active learners tend to retain and understand information best by trying things out and doing something active with it - discussing or applying it or explaining it to others, working in a team, in the external world. Reflective learners prefer to think about it quietly first and prefer to work alone. They prefer examine and manipulate information introspectively. This dimension is identical to the Active Experimentation, Observation and Reflection on the Kolb Model and is related to the Extravert/Introvert scale of Myers-Briggs Model.
- **Sequential/Global** – Sequential learners absorb information and acquire understanding of material in small, incremental and connected chunks. Global learners take in information in seemingly unconnected fragments and achieve understanding in large steps. When they are able to make the "total picture" they can often see connections that escape to sequential learners. Before global learners can master the details of a subject they need to understand how the material being presented relates to their prior knowledge and experience.
- **Inductive/Deductive** – Inductive learners reasoning from particulars (observations, measurements, data) to generalities (rules, laws, theories). They make observations and then infer or correlate principles Deductive learners proceed in the opposite direction. They start with axioms, principles or rules, deduce consequences and formulate applications. A large percentage of classroom teaching in every subject is primarily or exclusively deductive, probably because deduction is an efficient and elegant way to organize and present material that is already understood.

The ILS instrument is composed by 44 questions, 11 for each of the four dimensions previously described. This questionnaire can be easily done through the web [12] and provide scores as 11A, 9A, 7A, 5A, 3A, 1A, 1B, 3B, 5B, 7B, 9B or 11B for each of the four dimensions. The score obtained by the student can be 1-3, meaning that the student has a weak preference for one dimension so he/she is reasonably well balanced on the two dimensions of that scale; 5-7, meaning he/she has a moderate preference for one dimension of the scale and will learn more easily in circumstances that favor that dimension; 9-11, meaning that he/she has a very strong preference for one dimension of the scale and probably has a big difficulty in learning in a situation that does not support that preference. The letters "A" and "B" refer to one pole of each dimension.

Although the Felder Model includes the Inductive/Deductive dimension, it is not measured in the ILS because the author believes that the best method of teaching is induction. However, there is considerable evidence that incorporating a substantial inductive component into teaching promotes effective learning [13]. Inductive reasoning is thought to be an important component in academic achievement [14]. Cognitive research emphasizes the importance of prior knowledge in learning [15]; introducing new material by linking it to observed or previously known material is essentially inductive. The benefits claimed for inductive instructional approaches (e.g., discovery or inquiry learning) include increased academic achievement and enhanced abstract reasoning skills [16], longer retention of information [17-18] and improved ability to apply principles [19].

THE PROPOSAL

In this section we discuss the type of activities that can be used to support different learning styles during programming learning. The objective is to devise activities that can be supported by an e-learning tool.

We will focus on the categories defined by Felder's model. We used this model in an experiment [20] where we used the ILS to characterize our engineering students. We chose it for several reasons, but especially because its author has an engineering background and the model development was focused in that field.

The experiment took place in the second semester of 2005/2006 academic year and involved 29 volunteer students enrolled in Informatics Engineering course of Superior Institute of Engineering at the Polytechnic Institute of Coimbra. Most of these students (26) had failed the Introductory Programming course in the first semester, and the remaining 3 were freshmen. All these students had severe difficulties in programming learning. In that study, we wanted to verify if we could find some correlation between each student learning style and her/his difficulties and the type of errors they most often did. We used typical programming problems, but also other type of exercises (requiring logic reasoning, mathematic skills and especially ability to solve problems). Then we tried to find a connection between each student learning style and the strategies she/he uses to solve problems. Although we did not find a clear correlation we obtained some useful conclusions about the way they solve problems. Consequently, we are bringing in these ideas to a web based system to support programming learning.

From the experiments and as expected, the verbal learners were able to better understand problem specifications and give better text based solutions. Visual learners reached better performance in exercises including figures and seemed to have more facility in writing their answers using graphics. We could verify that "strongly visual" students had big difficulties to express themselves in textual mode. We even had cases where textual answers seemed wrong when the student reasoning was in fact correct. What really happened was that they couldn't express their ideas well enough in a textual format and sometimes even wrote things that didn't correspond to their intentions. On the other hand, these student's graphically expressed solutions were usually very intelligible (although not necessarily correct). So, to be effective to this type of students the e-learning environment must have a strong support to visual communication. This must happen not only in the way the environment proposes activities and contents, but also how students are allowed to create solutions. It is necessary to facilitate the use of diagrams, flowcharts, and other visual representations. Films or live demonstrations should be presented whenever possible [21].

But we can't consider only one dimension of a student's learning style. For example, a student categorized as visual can be active/visual or reflective/visual. Concerning this aspect we concluded that most reflective/visual students that have a moderate score in the reflective dimension presented a textual solution, before concluding with some illustration. A lot of active/visual students gave the answer only through figures or graphics and, in some cases, complemented it with a small text. The reflective/visuals, with a strong reflexive component, gave their answer firstly trough a textual description and rarely complemented it with any illustration. The illustrations used were more complete as students were more visual. Also their textual explanations were more detailed as they were more reflexive. Taking into account these findings, we think that the e-learning environment must be adaptable, emphasizing more or less the visual/textual representations according to the reflective/active dimension of the actual student. Activities proposed should also be diversified, including problem solving activities, recorded lectures, and discussions about programming principles and techniques.

In the experiment we also verified a big difference in the answers given by students categorized as globals and sequentials. In general, the sequentials described their answers in a more step-by-step way than the global learners. On the other hand, globals tend to skip some stages in their solutions. We also confirmed that sequentials have difficulties to generalize solutions for the problems. These findings can give valuable suggestions about the learning sequence that should be proposed to each student. Interaction during the activities should also be adapted, for example asking for more detailed answers for global students, as they tend to skip details and give too concise answers. Most formal education involves the presentation of materials in a logically ordered progression, so in a sequential way. Learning this way can be a difficult experience for global learners. To reach the global learners the e-learning environment that we propose must provide the big picture or goal of a topic or problem, before going into details. It is important to establish the context and relevance of the problem and to relate it to the students' experience. Applications and "what if" activities should be widely used [21].

Concerning the sensory/intuitive learners, it was verified that some students categorized as sensory tend to solve exercises limiting themselves to a given example (generally included in the problem specification) and not generalizing their answer to any input data. The results also showed that, in general, the sensory learners presented weak abstraction capacity in all problems where this skill was necessary. In this case the proposed environment has to include a higher diversity of examples and test data to propose to the students categorized as sensorials. It is important to make them create generic solutions and show that specific solutions have no use with other input data. To be effective the environment must reach both types, rather than directing itself primarily to intuitors as it is common in a traditional approach. The materials presented and used in activities should be a blend of concrete information (facts, data, and observable phenomena) and abstract concepts (principles, theories, mathematical models) [11, 20]. Concrete experience and abstract conceptualization are two poles of a learning style dimension in Kolb's experiential learning model that is closely related to sensing and intuition.

Although in our experiments we used Felder's model, we think it is also important to acknowledge the existence of other models and the relationships between them. For example, we can notice that the active/reflexive dimension in Felder model corresponds to the "Active Experimentation"/"Observation and Reflection" in Kolb model and is related to the Extravert/Introvert scale of Myers-Briggs model. Studying and experiencing with other models can give further insights on how to better reach all students and how to accommodate student's differences, so that we can create good learning conditions to all. That is the main objective of the programming learning environment currently in development in our group.

CONCLUSION

The availability of an adaptable computer-based programming learning environment can have big advantages to students, especially those with deeper difficulties. To be more effective, learning activities should be adapted to each student characteristics and needs. As students progress and learn, their needs will also change. That's why it is important the learning environment can have updated information about each student progress.

In this paper we discussed how learning styles information is being used in the design of a new learning environment that may help students to learn programming easier. Of course, other dimensions are being considered, such as knowing when students should learn individually or in group, and how it is possible to stimulate the creation and sustainability of learning communities involving programming students, so that it is possible to create a richer learning context. We hope that when ready, this environment may help our students to improve their results in programming learning.

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