Learning styles and problem solving strategies

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ABSTRACT
A number of barriers found by novice students in programming learning motivated many researchers to work in this field. One of the causes of the students' failure in introductory programming course is their inability to solve problems using computers. This paper reports some results of an experience aimed to help some students to improve their problem solving skills. Learning styles concepts and instruments were employed to categorize the students in groups, in order to analyze if there was any correlation between these learning styles and the way they solved problems.

Keywords
Learning styles, computer science education, problem solving

1. INTRODUCTION
A lot of attention has been focused lately on the difficulties felt by many novice students in learning how to program. In fact, high failure rates in initial programming courses motivated several authors to investigate the causes of those difficulties [1-3]. Also, several tools have been proposed to help student learning, many based on animation and visualization of algorithms and programs. Although some of these tools have been reported to have a positive effect in student learning [4-5], the number of students that drops out or fails those courses is still remarkably high.

People learn in several ways and have different preferences when approaching 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. Due to the different preferences in the way people perceive and process information, learning styles are a useful instrument to help students and teachers understand how to improve the way they learn and teach.

Some researchers have studied the relationships between students' learning styles and their performance in introductory programming courses [6-7]. Another important aspect is to know how students with different learning styles approach problem solving, and what type of representations they prefer to use to express their solutions. In particular we were mostly interested in students who had failed in initial programming courses and still show huge difficulties in solving even simple programming problems. With these objectives in mind we made some experiments that will be described in this paper.

In the next section we describe some models available in the literature to describe and categorize learning styles. In section 3 we present the experiments made and some results. Finally, we present some conclusions and future work.

2. LEARNING STYLES MODELS
According to Keefe [8] "learning styles are 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 styles models were proposed with the objective of classifying and characterizing how students receive and process information. Some well known examples are Myers-Briggs, Kolb and Felder-Silverman.

The Myers-Briggs model was developed by Isabel Myers and Katherine Briggs to classify personality types. It follows Jung's Theory of Psychological Types [9]. The Myers-Briggs Type Indicator – MBTI defines four scales: Extraverts/Introverts, Sensors/Intuitors, Thinkers/Feelers and Judgers/Perceivers. In spite of this model being 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.

In Kolb's model the student's experience is emphasized and plays an important role in the learning process (according to Kolb, learning is a process acquired through the transformation of experiences [10]). The model defines a repetitive cycle of learning composed of four stages: Concrete Experience (EC), Observation and Reflection (OR), Abstract Conceptualization (CA) and Active Experimentation (AE). The cycle's first stage, EC, includes concrete experiences, like seeing, listening, and feeling. The second stage, RC, includes observations and reflections about previous experiences. In the CA stage students integrate and transform those observations and reflections in theories and concepts. Finally, the theories are used to make decisions and to solve problems in the AE stage.

2.1 Felder–Silverman Model

To Felder “a student’s learning style profile provides an indication of probable strengths and possible tendencies or habits that might lead to difficulty in academic settings. The profile does not reflect a student’s suitability or unsuitability to a particular subject, discipline, or profession” [12].

The emphasis in Felder-Silverman Model is on preferred learning style, not on ability [13]. According to this model a learner is classified in five dimensions, Sensory/Intuitive, Visual/Verbal, Active/Reflective, Sequential/Global, Inductive/ Deductive.

The dimensions Sensory/Intuitive and Visual/Verbal refer to information perceiving mechanisms. The dimensions Active/Reflective and Sequential/Global are about how the information is processed and transformed in understanding.

- Sensory/Intuitive – Sensory learners like to study facts and solve problems by using known methods. They tend to be more oriented to details, like practical work, and are good to memorize things. Generally they don’t like surprises and complications. Intuitive learners feel comfortable with abstract concepts. They like to find out new possibilities and application to the studied topic. They tend to be innovative and don’t like repetitions. This is similar to the Sensors/Intuitors dimension of the Myers-Briggs Model;
- Visual/Verbal – Visual learners learn better what they see as figures, maps, diagrams, films, and flowcharts. Verbal learners prefer written or spoken explanations;
- Active/Reflective – Active learners absorb information by trying things out and working in teams. They tend to focus on the outer world. Reflective learners prefer to think first about the information and like to work alone. They tend to focus on the inner world of ideas. This dimension is identical to the Active Experimentation, Observation and Reflection in the Kolb Model and is related to the Extrovert/Introvert scale of Myers-Briggs Model;
- Sequential/Global – Sequential learners learn in orderly, incremental steps. Generally they have more learning success because the majority of books used by professors are sequential. Global learners tend to learn in large steps after accumulation of all the facts;
- Inductive/Deductive – Inductive learners organize the information starting from particular reasoning toward generalities. They infer principles. The deductive learners organize the information in a way by which the solutions for the problems are consequences of a general idea. They deduce principles. The traditional teaching method is deduction, starting with theories and proceeding to applications.

To identify students’ learning preferences, Richard Felder and Barbara Soloman developed in 1991 the Index of Learning Styles – ILS. This instrument is a set of 44 questions, 11 for each of the first four dimensions described above. Although the model includes the Inductive/Deductive dimension, it is not measured by the ILS, because the author believes that the best method of teaching is induction, whether it is called problem-based learning, discovery learning or inquiry learning [14].

The instrument provides the scores 11A, 9A, 7A, 5A, 3A, 1A, 1B, 3B, 5B, 7B, 9B, and 11B for each of the four dimensions. The letters “A” and “B” refer one pole of each dimension (see Figure 1). For instance, if a student has a 1B score for the dimension Active/Reflective it means that he/she is reflective (B) with a score of 1.

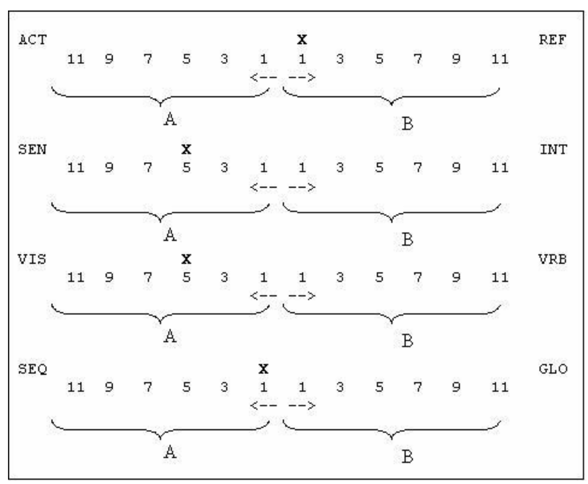

Figure 1. Learning Styles Results

The classification of a student according to his/her score in a dimension can be “fairly” (1-3), “moderate” (5-7) or "strong" (9-11). A person classified as "fairly" does not show preference for any of the two poles of that dimension. The "moderate" indicates that the learner has a "moderate" preference for one pole of the dimension and will learn better in a teaching environment which favors that pole. The "strong" indicates the learner has a very "strong" preference for that pole. This learner may have real difficulties learning in an environment which does not support that preference.

2.2 Teaching Techniques to address student's Learning Styles

It is worth noting that all learning styles dimensions are useful in the engineering field. Naturally, the ideal case would be one where the teacher creates a heterogeneous environment that matches every student's learning style. Felder proposed some teaching techniques that may be useful for that purpose [14].

To be effective for both sensory and intuitive students, learning materials should provide concrete information, but also abstract concepts. Also, sensory students tend to like receiving rapid feedback for their work, as they need to know if they are in the right track.

To reach visual learners Felder recommends the engineering educators to use visual materials, like pictures, diagrams, and films. Other authors suggest the use of practical visualization and animation tools. These tools can help visual, sensory, and active learners.

To accommodate active and reflective learners the instructors should alternate lectures with occasional pauses (10-15 minutes) to allow reflection, followed by discussions and/or problem-solving activities to reach active students. These short pauses tend to keep reflexive students engaged and active throughout the lecture.

Finally, to reach global learners, the instructor should provide a big picture about a topic before presenting its details. It is also important to highlight possible connections between the subject and the students' experiences. In addition, in engineering education, the global learner should be able to choose his/her own problem solving methods and strategies.

Many times class constraints, namely size and time, make it difficult for teachers to follow all Felder's recommendations. Anyway, careful planning and the consciousness that students learn differently may help teachers to create more productive environments for all their students.

3. THE EXPERIMENT

The experiment took place in the second semester of 2005/2006 academic year and involved 29 volunteer students enrolled in the Informatics Engineering course of the 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. These students had shown strong difficulties in programming learning. To help them we developed a set of exercises that require logic reasoning, mathematic skills, and the ability to solve problems. They were proposed to those students during weekly sessions throughout the semester. Most proposed exercises involved concepts in some way related to typical introductory programming problems. The students could give their answers in different ways, as Portuguese, pseudo-code or a programming language [15].

We took advantage of this work to make some research concerning learning styles and their influence on the students' work.

We used the Felder-Silverman model, namely the ILS, to characterize our students. Then we tried to find a correlation between each student's learning style and the way she/he solves problems. One of the reasons we chose ILS is because Felder's model is focused on the engineering field and all students involved in our researcher are engineering students. Another reason is because Felder-Silverman model, as discussed in section 2.1, has similar dimensions to the models: The Sensory/Intuitive dimension, for instance, is identical to the Sensors/Intuitors dimension of the Myers Briggs Model; the Active/Reflective is similar to the Active Experimentation, Observation and Reflection stages of Kolb's Model and also related to the Extravert/Introvert scale of the Myers Briggs Model. Finally, the cost was another factor that contributed to our choice. The ILS is freely available on the Web.

3.1 Student Characterization

We started by asking the students to answer a Portuguese translation [16] of the ILS questionnaire. The students were given a printed version of the questions and answered them online, through the ILS official website [17]. The results obtained were generated automatically by the website and are shown in table 1.

Table 1: Summary of results for each ILS dimension

Dimension	Number
Sensory	21
Intuitive	8
Visual	26
Verbal	3
Active	15
Reflective	14
Sequential	20
Global	9

In some aspects our results are consistent with those published in other studies, but in other aspects there are some differences. Research conducted in the computer science field by Layman [18] reported that students are more sensory than intuitive, which is similar to our results. Our findings suggest also that most students are more visual than verbal. Similar results were found by Thomas [7]. We found a small difference between the number of active and reflexive students. This difference was also verified by Layman and Thomas, but with a larger variation. Regarding the Sequential/Global dimension the differences were expected, although a lot of sequential students in our experience presented a "fairly" score.

It was possible to divide some students into small groups according to their learning styles, as shown in Table 2. The remaining students could not be grouped as each one had a different learning style. The column "Average" shows the average grade obtained by each group members in 3 tests they answered during the semester.

Table 2: Group Result

Group	Number	Average
Sensory, Visual, Active, Global	4	59.19 %
Sensory, Visual, Active, Sequential	6	61.02 %
Sensory, Visual, Reflective, Sequential	8	59.61 %
Sensory, Visual, Reflective, Global	2	49.29 %

3.2 Student Works Analysis

As expected, visual learners showed better performance in exercises that include figures and seemed to have more facility in writing their answers using graphics. To test this possibility we asked the students to solve the following problem: "Given an integer, describe the procedure to calculate the sum of its digits". The students were asked to describe the general process and to indicate all their solution steps, using both text and graphics. We verified that the "Visuals" had a better performance using graphics than text. If we had only the latter form we could conclude that these students weren't able to solve the problem. But, what really happened was that they couldn't express their ideas well enough in a textual form.

It was also observed that many visual students developed poor or insufficient solutions to the problem. On the other hand, verbal learners were able to give better text based solutions, as expected. The textual descriptions given by "Visuals" were frequently incomplete or ill-explained, but their solution's graphical expression was, in general, very comprehensible (although not necessarily correct). Sometimes we also verified that "Visuals" difficulties in expressing themselves in a text form were so high that they couldn't write exactly what they really wanted to say. For example, we verified that a visual student wrote in his text solution the statement "x takes the value of y", but finished his description with the formula x=x+y. So, his textual answer was wrong, but if we consider the formula the answer is absolutely correct.

We concluded that the majority of Reflective/Visual students that had a "moderate" score in the reflective pole 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, with a small text.

This aspect was strongly verified, for example, in the next question: "Suppose you have a set of 4 square shaped boxes whose side lengths are L1, L2, L3 and L4 and that L1<L2<L3<L4. Knowing that L1 is inside L3 and L2 is inside L4, describe the procedure to place them all inside each other". In this problem all the students classified as Active/Visual with a "strong" score in the active pole, answered uniquely through figures that included arrows to illustrate the process. The Reflective/Visual learners, with a "strong" reflective component, gave their answer firstly through 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 reflective.

As mentioned earlier, the majority of students were sequential, although they were scored with 1, 3 or 5 in the sequential pole of the Sequential/Global dimension, meaning that this characteristic is not very "strong". In general, they described their answers in a more step-by-step way than the global learners. The "Globals" tend to skip some stages in their solutions. Particularly, we confirmed that the "Sequentials" have difficulties in generalizing solutions for the problems. This was verified in the next question: "Describe the process to verify the win in a "tic-tac-toe" game". The game is represented by a bi-dimensional array with indexes in the range 0 – 2. Each cell could assume the values 0 (empty), 1 (player one) or 2 (player two). We verified that the "Sequentials" tested if the line values were equal, but also which player had won. However, the "Globals" only verified if someone won, that is if all values in a line were equal. Additionally, the "Globals" were able to reach a general expression to verify all the lines through the use of a cycle with an index that was automatically incremented. The "Sequentials" needed to repeat the code for each line and didn't use cycles to describe repetitive actions.

It was also observed that most global learners gave excellent answers to some questions, but didn't even try to answer some others, leading to a poorer total classification than the "Sequentials". It is difficult to find a full explanation to this fact, but we suppose that "Globals" need more time to answer the questions as they need to reach a general strategy before they work out the details.

Another aspect that is worth mentioning concerning the "Sequentials" versus "Globals" comparison was evidenced by the next question, included in the final test. We gave to the students the code that makes the drawing shown in figure 2. We asked them to indicate the value assumed by each variable in each step of program execution. Then, they were requested to draw the final picture resulting from the code initially given. Almost all students were able to answer the first question, although most of them couldn't calculate the precise value of the coordinates. This was due to their difficulties to use the cosine and sine concepts and values. However, only a small number of students answered the second question. Curiously, all of them were "Globals".

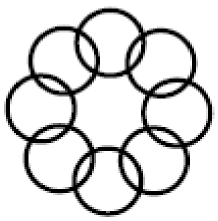

Figure 2: Picture used in an exercise

In what concerns the Sensory/Intuitive dimension, it is important to notice that most students categorized as "Sensory" had a "moderate" or "strong" score, but among the "Intuitives" only one student presented a "moderate" score (the others had a "fairly" score). However, this "Intuitive" learner had the best performance in almost all questions of the tests. Perhaps, because the majority of the questions involved a good abstraction capacity and innovative concepts, with which the "Intuitives" feel more comfortable. In this context we can mention the following problem. "A man is on a step of some stairs. He goes up 5 steps, then goes down 7, after that he goes up 4 and later more 9 to reach the top of the stairs. How many steps have the stairs?" We verified that only a few students were able to represent their solution through a correct mathematical expression. All of them were "Intuitives".

Additionally, it was verified that some students categorized as sensory tended to solve exercises limiting themselves to the given example (demonstrating what was required) and not generalizing their answer to any input data. For example, we put the next question: "A triangular number is one that is equal to the sum of the first natural numbers (for example, 6 (1+2+3) and 10 (1+2+3+4) are triangular numbers). A triangular number can be represented by a triangle. For example, the number 6 can be represented by:

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Indicate how to construct a right-angled triangle with asterisks, corresponding to a triangular number".

All students that proposed a solution specific to the given example (number 6), instead of a general solution, were categorized as sensory. The results also proved that, in general, the sensory learners presented weak abstraction capacity in all problems where this skill was necessary.

Finally, we observed that the students that had a "fairly" score in all ILS scales of preference also had poor performance in most exercises. We don't have a clear explanation to this fact. Perhaps this happened just because the number of students in this situation is low and they had a previous lower preparation on problem solving and programming.

We have to stress that the number of students surveyed wasn't enough to conclude that there is a pattern or a correlation between the way they solve the problems and their learning style. All results reported in this paper have to be seen as preliminary. Future work is necessary to validate or refute these observations and also to widen the scope of our investigation, namely involving a full freshman course and not only students with previous difficulties in programming learning.

4. CONCLUSION

Low problem solving skills is one of the factors that lead a good number of students to failure and frustration in their introductory programming courses.

There are several ways to solve and understand problems and concepts. This experience involved a group of students with programming learning difficulties. We presented them a set of activities that included mathematics problems, general problem solving, and logic reasoning. We analyzed the students' answers taking into consideration their learning styles preferences.

Our experiences were restricted to problem solving aspects and we did not address the way students acquire knowledge. So we have no conclusions about the adequacy of the instructional strategies used. As future work we intend to investigate how to improve teaching strategies in introductory programming courses, taking into account students' learning styles.

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