The Impact of Learning Styles in Introductory Programming Learning

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Abstract - **There is a widespread concern about the difficulties felt by novice students in introductory programming courses. During the last years, new tools and methodologies were proposed to support students in their programming learning activities and improve the teaching quality. In general, these proposals focused on the effectiveness of teaching and learning processes. Our work focuses on students' behavior and preferences when solving specific programming problems. We applied Felder and Soloman's Index of Learning Styles instrument to 97 students enrolled in an introductory programming course to collect information about their learning styles. Next, during four months we observed some student's behavior when solving programming problems. Then, we compared the data obtained with the students learning styles to identity some possible patterns and verify if there is some correlation between students' learning styles and their performance. We also used the students' final grades in the course to see if we could find some pattern. In this paper we will describe in detail this experience and discuss some of the most relevant results.**

Index Terms - Computer science education, Learning styles, Programming

INTRODUCTION

A pedagogical strategy may be effective to a group of students, but have little effect to some others. This may be caused by the different preferences people have in the way they receive and process information [1]. Differences between student's learning styles and teaching strategies used by instructors can reduce the interest of students and affect their performance on some subject or discipline [2]. In this context, it is important for instructors to have knowledge of students' individual learning styles and take them into consideration when designing, developing and delivering educational materials and activities [3].

Literature [4] – [5] reveals that difficulties in learning to program are a global problem felt by students of different universities around the world. To face this problem many teachers and researchers have proposed many strategies and tools that might help reducing student's difficulties [6]-[8]. However, the problem still exists, as high drop out and failure rates continue to be reported. Hence, it is important to look for new ways that may prove more effective in supporting programming learning. In particular, we think it is important to take each student learning style into consideration when designing learning activities that may help her/him to learn. This is not a common situation, since many times the only possibility for lecturers is to use the same learning materials and strategies to all students. These will probably be adequate for some part of the students, but a poor approach to some others. The reason for this difference may well reside on the different learning styles students have.

The main purpose of the present work was to verify if we could find any relationship between students's learning styles and their performance, problem solving strategies and attitudes, in a conventional introductory programming course. During the fall 2006 semester we followed 97 students (65 were freshmen and 32 were repeating the course because they had failed it in the previous year). Among the freshmen, 47 declared not having any previous programming experience. We used an online instrument, 'The Index of Learning Styles' developed by Felder and Soloman [9], to determine each student predominant learning style. At the end of the semester we analyzed the final results obtained by those students and their learning styles to see if we could find some pattern. Also, during four months we observed some of those students solving typical programming exercises in class. We used a screen recording tool and saved each student's actions during problem solving, so that we could later analyze their strategies and compare them with their learning styles.

In the following section we give an overview about some learning styles models proposed in literature, giving more emphasis to the model developed by Felder and Silverman, since this is the one we chose to use. Then, we discuss some teaching strategies proposed in literature to accommodate the different learning styles that usually exist in most courses. In the next section we present our study and discuss the results obtained. And finally, we present some conclusions.

LEARNING STYLES MODELS

According to Keefe [10] '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 to classify and characterize how students receive and process information. Some well known are Myers-Briggs, Kolb and Felder-Silverman. We will briefly describe the two first one and will be more detailed in the last one, since we used it in our study.

The Myers-Briggs model was developed by Isabel Myers and Katherine Briggs to classify personality types

[11]. It follows Jung's Theory of Psychological Types [12]. 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 [13] 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). 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 first stage, EC, includes concrete experiences, like seeing, listening, and feeling. Next, 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 stage AE.

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 [14]'.

The emphasis in Felder-Silverman Model is on preferred learning style, not on ability [1]. 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 dimension Sensors/Intuitors of 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 work 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 and teaching strategies 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 Learning Style – 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 [2].

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.

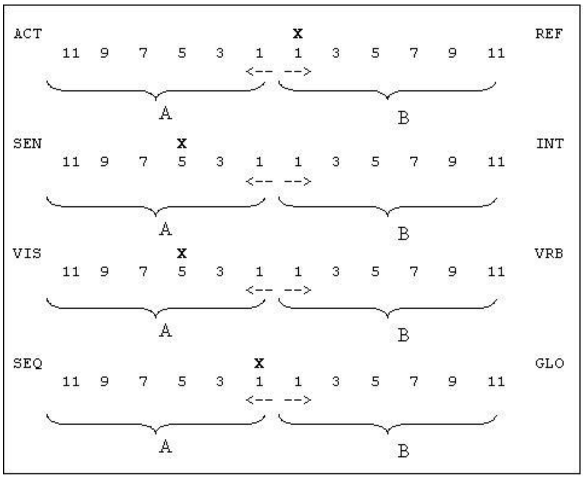

FIGURE 1
LEARNING STYLES RESULTS

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.

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 learning style. Felder proposed some teaching techniques that may be useful for that purpose [2].

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. In this way, the use of practical visualization and animation 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 Reflective 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 difficult for teachers to follow all Felder recommendations. Anyway, careful planning and the conscience that students learn differently may help teachers to create more productive environments for all their students.

OUR STUDY

The "Introdução à Programação e Resolução de Problemas" (Introduction to Programming and Problem Solving) is the first programming course required to all Informatics Engineering students at the University of Coimbra. It is placed in the first semester of the first year. This course uses Python as the implementation language and Dr Python as development environment. In each week, the course has two hours of lectures, two hours assisted labs (usually 24 students with a Teaching Assistant present) and two hours of open lab where a PhD student is available to help students.
Our experiment was realized during the fall 2006 semester (October 2006 – January 2007) and was divided in four steps.

In the first step the ILS instrument was administered to all course students that were present in the semester first week assisted labs. However, as 24% of the students did not answer all ILS questions we ended up with 97 valid profiles.

The second step consisted on the direct observation of 17 students during their problem solving activities in assisted labs. These students were all freshmen with no previous programming experience. This observation was carried out by two researchers during two weeks.

In the third step, instructors asked the same 17 students to allow recording of their actions during a practical test. However, only 4 of them authorized, as the others didn't feel comfortable being recorded during a test. We then decided to invite other students, also freshmen with no previous programming experience, to participate. In the end, a total of 7 students volunteered and we used a screen record tool to save in video format all steps they made while trying to solve the test exercises.

Finally, in the fourth step we used the course final grades to see if we could find a pattern that connects the grades with the students learning styles. In this course the final grade was obtained through a written exam (35%), a set of small exercises solved in the assisted labs (15%) and some assignments solved outside class, but defended individually before one of the teachers (50%).

RESULTS AND DISCUSSION

Table I shows the 97 student distribution in each ILS dimension. In general, these results were similar to a prior experiment we conducted in the second semester of 2005/2006 with students from another higher education institution [15].

TABLE I
SUMMARY OF RESULTS FOR EACH ILS DIMENSION

Dimension	Percentage
Active Reflective	71% 29%
Sensory Intuitive	79% 21%
Visual Verbal	92% 8%
Sequential Global	67% 33%

Using these results, it was possible to divide some students into small groups according to their learning styles, as shown in Table II.

TABLE II
DISTRIBUTION OF STUDENTS BY GROUPS OF LEARNING STYLES

Groups of Learning Styles	Total Students	Percentage
Active/Sensory/Visual/Sequential	35	36.08%
Active/Sensory/Visual/Global	16	16.49%
Reflective/Sensory/Visual/Sequential	15	15.46%
Active/Intuitive/Visual/Global	8	8.25%
Active/Sensory/Verbal/Sequential	5	5.15%
Active/Intuitive/Visual/Sequential	4	4.13%
Reflective/Sensory/Visual/Global	4	4.13%
Reflective/Intuitive/Visual/Global	4	4.13%
Reflective/Intuitive/Visual/Sequential	3	3.09%
Reflective/Sensory/Verbal/Sequential	2	2.06%
Active/Intuitive/Verbal/Sequential	1	1.03%
Total	97	100%

In Table II, we can see that the students learning styles were divided in 11 different groups. We can also verify that the first three groups included about 68% of the students.

Another important aspect about learning styles is the student's scores (strong, moderate, and fairly) in each pole of each dimension. The graphic shown in Figure 2 shows the results obtained in this aspect.

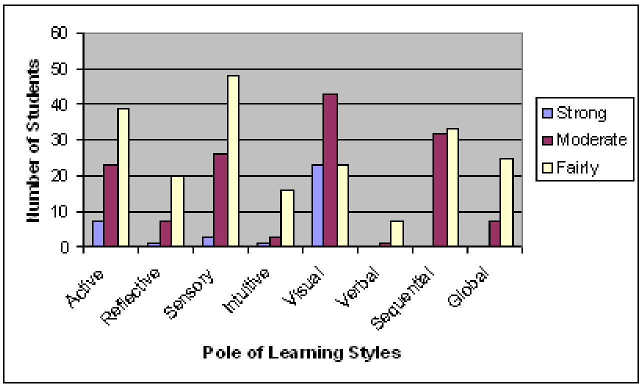

FIGURE 2
SUMMARY OF THE STUDENT'S LEARNING STYLES SCORES ACCORDING TO EACH POLE

We can see that in most poles the students presented a fairly learning style score. The only exception was the Visual pole. Among all poles the Visual has the highest number of students and most of them had a moderate or strong score in this pole. In opposition to that, the Verbal pole has a fewer students if compared to other ones. Also, all students that belong to this pole presented a fairly or moderate score.

As Table III shows, in the experience second and third stages we observed students belonging to different learning styles groups. As said before some of these students participated in both stages, while others just participated in one of them.

TABLE III
SUMMARY OF STUDENTS THAT PARTICIPATED IN THE EXPERIENCE SECOND AND THIRD STAGES

Group of learning styles	Num. of Students	2nd Stage	3rd Stage
Active/Sensory/Visual/ Sequential	6	6	1
Active/Sensory/Visual/ Global	8	7	3
Reflective/Sensory/Visual/ Sequential	5	4	2
Reflective/Intuitive/Visual/ Sequential	1	0	1
Total	20	17	7

Regarding to the experience fourth stage, we can observe in Table IV the distribution of students for groups of learning styles and the percentages of those students that passed and failed the course.

We can see that 63% of students failed in this Introduction to Programming and Problem Solving course. Most of the students are Active/Sensory/Visual/Sequential. However, 69% of these students failed. On the other hand a few students are Reflective/Intuitive/Visual/Sequential, but all of them succeeded.

Results also show that we couldn't confirm the expected results concerning Sequential versus Global students. Results show that 38% of the involved sequential students were approved, and 34% of the global students were also approved. This difference is smaller than we expected.

We could verify some behavioral tendencies in Active/Sensory/Visual/Sequential students. They tended to develop their answers step by step and, for each step, they used to run the code written so far. This shows their strong necessity to see concrete results and rapid feedback. When they found some difficult to solve a problem, generally they stopped and started solving the next question. Also, they generally spent little time thinking how to find a correct solution for a problem. For example, in a class it was proposed to students a set of three exercises. Some students started all three exercises almost simultaneous, jumping from one to the other, and when the time given by the instructor finished, many of them didn't have any of them completely solved. In general, most of these students used essentially a trial and error approach. Perhaps, these students lack of patience and reflection led many of them to fail the course. As we can see, although most students belong to this group the majority had failed.

TABLE IV
DISTRIBUTION OF STUDENTS BY GROUPS OF LEARNING STYLES AND RATES OF SUCCESS MEASURED BY FINAL GRADES

Groups of Learning Styles	Total Students	Students that Passed	Students that Failed
Active/Sensory/Visual/ Sequential	35	31%	69%
Active/Sensory/Visual/Global	16	25%	75%
Reflective/Sensory/Visual/ Sequential	15	40%	60%
Active/Intuitive/Visual/Global	8	50%	50%
Active/Sensory/Verbal/ Sequential	5	60%	40%
Active/Intuitive/Visual/ Sequential	4	25%	75%
Reflective/Sensory/Visual/ Global	4	50%	50%
Reflective/Intuitive/Visual/ Global	4	25%	75%
Reflective/Intuitive/Visual/ Sequential	3	100%	0%
Reflective/Sensory/Verbal/ Sequential	2	0%	100%
Active/Intuitive/Verbal/ Sequential	1	100%	0%
Total	97	37%	63%

Regarding the Active/Reflective dimension, we can identify that reflective students developed more consistent answers to the proposed questions. Generally, when he/she decided to run the code it was correct. They do not need to run fractions of the code as the active students. In many situations, active students run pieces of code with severe logical and syntactical problems aiming to see some result, even error messages. Consequently, the Active students tended to have more syntax errors than the Reflective. Perhaps this happened due to the concern that Active students showed to give an answer, even if it was not completely correct. The Reflective students in general did not use a trial and error approach as happened with Active students.

Concerning the Visual pole, it is worth noticing the high number of students that had moderate or strong scores. In addition, most sets of proposed exercises had at least one question involving drawing some geometric figure on the screen. For this kind of question almost all students developed a solution or tried to present one. This behavior was not observed for the other questions.

One interesting aspect verified with Global students is their tendency to stop the solution development and start again from scratch when they found difficulties that they couldn't solve immediately. For example, it was very common for these students to stop writing code on the IDE and take no further step to reach the solution following that line. On the contrary, they erased all code and started to write a new solution. This behavior was not observed in Sequential students.

CONCLUSIONS

The differences between teaching strategies and students learning styles can affect their performance and reduce their interest in a course. So, it is important for instructors to know their students learning styles and take them into account when designing materials and teaching strategies.

During our experience we applied the ILS to students involved in Introduction to Programming and Problem Solving course and compared their learning styles with their behavior when solving some typical programming problems.

The study identified different patterns in the students' behavior and related them with their learning styles profiles. We verified interesting differences on the Active/Reflective, Visual/Verbal, and Sequential/Global dimensions.

Of course several other aspects could have been studied. As future work we intend to investigate possible relationships between learning styles and common programming errors, and also in strategies to minimize students' errors, taking into consideration their learning styles profile.

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