Effects of immediate feedback using ICT in a CS1 course that implements Mastery Learning

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Abstract— **This work in progress paper presents an innovative practice integrating concepts of Mastery Learning in a Computer Science 1 (CS1) course. *Mastery Learning* is one of the most used methods to achieve the personalization of learning, where students advance in content and learning evidence at their own pace with the particularity that they can only move to more advanced topics until they have mastered the previous ones. It is fully recognized that teaching the basic concepts of programming is one of the main challenges for teachers, they are constantly implementing innovative models to support this process. We believe that integrating the concepts of mastery learning in a CS1 course can be of benefit for students. In this case, an experiment centered on feedback, one of the pillars of mastery learning, was carried out.**

To identify if providing immediate feedback to students using Information and Communication Technologies (ICT) has some effect on learning, a Kruskal-Wallis test was performed to analyze the grades. In addition, a questionnaire was applied to students to measure their perception about the strategy. The results suggest that although the students' grades did not significantly improve, their perception towards this innovation is positive.

Keywords— Mastery Learning, Competencies Based Education, immediate Feedback, Personalized Learning.

I. INTRODUCTION

In the fall semester of 2017, we taught two CS1 groups in which we used an automated tool to give immediate feedback to students' class activities. In this specific case these activities consisted in several programming exercises. This tool supported one of the main pillars of mastery learning: feedback. Using this software, we were able to provide feedback and guidance to students, and this allowed them to go through the exercises of each topic at their own pace, and when possible, even solve more challenging problems.

The objective of this paper is to present the methods and strategies used in this implementation. Furthermore, we will present the results of the statistical tests that compared the grades between the groups where the innovation took place (experimental groups) with similar groups in which the innovation was not implemented (control groups), as well as the student's perceptions. Since the implementation of this learning experience was not defined as a formal experiment, and the selection of the students and groups was not under the control of the professors, the data collected from this implementation was analyzed using a quasi-experiment approach.

This paper is organized as follows: Section II presents the literature review, Section III presents the characteristics of the course and the strategy, Section IV explains the methods, Section V discusses the results. Finally, in Section VI the conclusions from this exercise are presented.

II. LITERATURE REVIEW

A. Mastery Learning

The mastery learning concept was developed by Benjamin S. Bloom who considered that professors should focus on individualized feedback to improve student's learning. According to him, although each student has specific characteristics that determine their ability to learn, all students can reach a high level of achievement if teachers provide them enough time and the appropriate conditions. He proposes to use the assessments, which usually are applied at the end of each learning unit, as an opportunity to improve the learning process and generate from them individualized feedback to students based on their results and defining corrective activities to help them master the topics of the learning unit. When students complete the corrective activities, they are given a new assessment that has the same objectives as the previous one but with different problems. The purpose of this second assessment is to verify if the activities assigned by the teacher to correct the deficiencies were useful to achieve the expected results. Therefore, students learn to appreciate the mistakes as tools that help them in the learning process. Bloom also recommends that teachers plan additional challenging activities at various levels for those students who demonstrate they have mastered the concepts since the first evaluation, so they can advance into more complex concepts that will increase their level of mastery. Meanwhile, the professor keeps working with students who are still trying to understand the basic contents [1].

This is the personalization of learning, in which all students can develop their skills either through corrective activities, which motivate them to learn from their mistakes, or with additional activities, which challenge them to develop skills at a higher level and allow them to reach their full potential.

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B. Related Work

In Guskey and Gates [2] several studies show that if mastery learning is implemented appropriately, students reach higher levels of achievement and develop greater confidence in their self-learning skills. They also show greater tolerance to frustration, perceive errors as part of the learning process and see them as opportunities for improvement. More recently, similar results are reported in Damavandi and Kashani [3] where students improved their performance and showed a better attitude towards chemistry learning. In Adeyemo and Babajide [4] an empirical study was conducted in a medium level physics class in which they found that the mastery learning strategy produces better results in student performance. In the same way, Titilope, Solomon and Solomon [5] found that under the mastery learning model students had a significant improvement in their performance. The mastery learning model establishes that students must master a given unit of instruction before moving on to the next one. But, how do we achieve this mastery? In areas like programming, one of the methods that has proved being effective is deliberate practice, which implies the constant exposure to practical exercises along with a close skills assessment that provides students with specific feedback. This enables the improvement of performance and development of competences [6]. On the other hand, according to Bennedsen and Caspersen [7], programming is recognized as one of the seven challenges of computer science education. Most new programmers have not developed skills given a problem description, to perform a decomposition of intermediate tasks and implement a solution. To face these challenges, we implemented a new approach for a CS1 course by using mastery learning supported by ICT tools to provide immediate feedback to students. The objective is to promote active participation, as well as to develop the basic skills that the computer science professionals require.

III. COURSE AND STRATEGY

A. The Course

During the fall semester of 2017 two Computer Science 1 (CS1) groups implemented the mastery approach. One of them was an honors program group. The enrollment requirements for the honors program in the institution include: higher grades and better TOEFL results than standard groups. As a result, students in honors programs are expected to perform at higher levels and to be challenged by teachers. Table I shows the description of the groups where the implementation took place.

B. The Tool

The tool used for this experience was Vocareum programming lab [8] it allows the professor to write the description of a programming exercise, to define the test cases the program must manage and to publish this exercise to students; it provides an online programming environment for students, auto grades students' work and provides immediate feedback. While working, students can see the exercise and start writing their program in the online environment, once they finish send the solution to be automatically graded.

When a solution is submitted the tool executes the students' program and compares its outputs with the professor's expected output, which were previously configured by the teacher. After this, Vocareum shows the feedback to the students. Fig. 1 shows an example of the feedback given by the tool. The professor can monitor students' submissions using the dashboard provided by the tool, here it is possible to see which students had sent the solution for each activity, the code provided and the corresponding grade for each submission; you can also add comments to students or change the grade assigned automatically by the tool if needed (Fig. 2).

TABLE I. DESCRIPTION OF THE GROUPS

	The honors program group	The standard group
Number of students	24	26
Weekly sessions	One 3-hour session	Two 1.5-hour sessions
Number of exercises per session	5	3
Difficulty level	Basic to High	Basic to Medium
Problem example	Copy the values of a two-dimensional array to a one-dimensional array by columns.	Given a two-dimensional array display the biggest value and the row and column where this value is found.

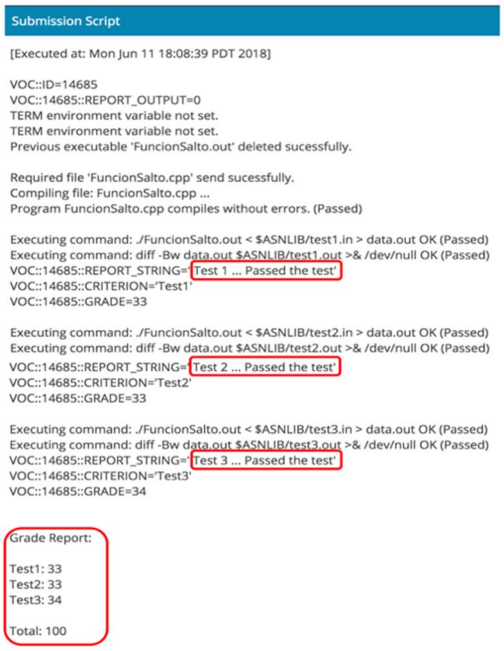

Fig. 1. Example of the feedback received by the students

C. The Strategy

The topics selected to implement the innovation include: decisions (IF), loops (FOR, WHILE), arrays and strings as the most challenging topics of this course. These were selected based on the experience of the teacher that implemented the mastery learning and students' feedback from previous semesters. For each one of these topics, several programming exercises were created, each one a little bit more complex than

Fig. 2. Example of techer's view. In the left side are the files, in the middle section is the student's code and in the right side the automatic grade assigned by the tool.

the previous. The planning of the exercises involved the definition of the problem, an example of the inputs and its corresponding expected outputs, as well as the creation of the test cases. When all the information was ready it was uploaded to the automated tool.

At the beginning of each class the professor published the first problem for all students, after that, and using the dashboard provided by the tool, the teacher monitored which students had sent the solution, the code provided and the corresponding grade for each submission. When at least two students had sent a correct solution, the next problem was released to all of them. This helped the professor to adjust the number and complexity of the exercises published in each session according to students' progress. During class students work on their laptops to solve the exercises and submit each program to the automated tool, which gives them immediate feedback about the correctness of the proposed solution. If the submission is marked as correct, they can move on to the next exercise; if it is not, they keep working on the current exercise, using the feedback from the tool and asking the teacher's help if needed, until they manage to submit a correct solution. It was observed during the sessions that while there were students working in the first exercise, others were on the third or fourth exercise, and others were even able to leave early since they finished all the exercises for the session before the class time ended.

IV. Methods

A. Comparison of students grades

Due to the size of the groups, it was decided to use the Kruskal-Wallis test as a non-parametric option to ANOVA, to identify whether the implementation of the mastery learning model, supported by an immediate feedback tool, has a significant impact in the students' exam scores for the selected topics. The comparison was made between each one of the groups in which the mastery learning methodology was applied (standard and honors) and control groups of each type from a previous semester, in which the innovation was not implemented. This was considered necessary due to the particular characteristics of each one of the types of groups that are offered in the institution.

B. Students perception

To evaluate the students' perception, a questionnaire was developed and applied. It included 8 closed questions with a 5-level Likert scale, in which 1 corresponds to the lowest level and 5 to the highest. The questionnaire was applied to both experimental groups using Google Forms to deliver it to the students. Each group received a different link to answer. The students' responses were compared using the Mann-Whitney test on the basis that some of the questions do not fulfill the normality assumption required to make a t-student parametric test.

V. Results

A. Grades Analysis

In the class a specific test in which the topics that implemented mastery learning were evaluated was applied. Table II shows the descriptive statistics of the grades for each one of the groups in the sample.

For the Kruskall-Wallis test the null hypothesis H_0 was the samples come from the same population, while the alternative hypothesis H_A was the samples do not come from the same population. Table III presents the result of this analysis. As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H_0. The risk of rejecting the null hypothesis H_0 while it is true is 11.18%. There is no significant difference on the students' grades as a result of the innovation.

TABLE II. Descriptive Statistics of the Groups

Variable	n	Min	Max	Mean	Std. Dev.
Grades | CSG	31	33.000	100.000	77.839	22.669
Grades | ESG	20	16.000	100.000	80.450	20.798
Grades | CHG	19	47.000	100.000	86.263	14.651
Grades | EHG	24	36.000	100.000	89.000	16.081

[a] CSG (control standard group), ESG (experimental standard group), CHG (control honors group), EHG (experimental honors group).

TABLE III. Krusskal-Wallis Test Grades Analysis

K (Observed value)	5.996246401
K (Critical value)	7.814727903
DF	3
p-value (Two-tailed)	**0.111792989**
alpha	0.05

B. Students Perception Analysis

Table IV shows the results of the Mann-Whitney test for each one of the 8 closed questions that collect students' perception on using Mastery Learning activities in their course. The first column contains the question, the second, the mean of the Honors group students' perception, the third, the mean of the Standard group students' perception, the fourth the p-value. Expressing the difference in the means as a null and alternative hypothesis, we have H_0, the distributions of the two groups are equal, and H_A, the means of the two groups are not equal.

TABLE IV. MANN-WHITNEY TEST COMPARING THE STUDENTS' PERCEPTION OF THE MASTERY LEARNING TECHNIQUE. HONORS GROUP VS STANDARD GROUP.

Question	Mean EHG	Mean ESG	p-value
1. According to my experience in this course, I consider that the automatic tool allows me to solve more exercises during the class session, compared with sessions where the tool has not been used.	4.375	3.880	**0.015**
2. The immediate feedback obtained when using the tool makes me feel more motivated to do the course exercises.	4.458	4.080	0.132
3. The use of the tool allows the professor to interact more personally with the students during the class session.	4.375	3.840	**0.035**
4. I consider that the tool allows me to perform the class exercises at my own pace.	4.750	4.320	**0.013**
5. I believe that making the class exercises at my own pace has a positive impact on my learning process.	4.917	4.520	**0.010**
6. I believe that the fact that the tool allows me to make the exercises at my own pace, without forcing myself to follow my classmates' pace, has a positive impact on my learning process.	4.708	4.320	0.079
7. I prefer to make an exercise, exam or programming challenge using the tool than the traditional way.	4.750	3.960	**0.008**
8. In general, I believe that the use of the tool impacts in a positive way in my learning process.	4.583	4.320	0.189

a. alpha=0.05

In the ESG the mean for all questions are lower than in the EHG. In general, it is possible to say that the students' satisfaction is lower for the standard group. On the other hand, it is possible to observe that for the EHG the mean for all questions is greater than 4. This can also be interpreted as a higher level of students' satisfaction towards the implementation of mastery learning using the automated tool for immediate feedback in the EHG. The previous finding is confirmed by the result of the Mann-Whitney test which shows that for questions 1, 3, 4, 5 and 7 there's a significative difference in the mean between the groups.

VI. CONCLUSIONS

Using the automated tool to implement the mastery learning methodology and give the students immediate feedback allows students to advance at their own pace. This has proved to provide a positive experience for both the students and the professor.

Even though students' grades are not significantly improved with this innovation, grades were not affected in a negative way and the satisfaction students refer towards this type of method is positive for a CS1 class.

Students from the honors program group have a greater positive perception towards the strategy implemented and refer that it has a positive impact on their learning process.

The professor's opinion is that being able to personalize the learning in a way that each student can advance at their own pace is the greatest advantage that the automated tool offers.

It is important to consider that the results of this implementation can't be generalized but can be considered as initial input for further implementations that can extend and analyze the effects of the immediate feedback in the mastery learning approach.

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