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ESTUDIO DE CASO

Learning Strategy for Programming Supported by Meaningful Learning, Brain-Based Learning, and Aesthetic Disposition

Estrategia de aprendizaje de la programación apoyado en aprendizaje significativo, *brain-based learning* y disposición estética

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Abstract

Objective: To analyze and establish if there is a relationship between the aesthetic distribution of elements on the board and its impact on the learning of computer programming.

Methodology: This study was conducted in parallel between two groups per semester from 2015 to 2018. The aesthetic elements referred to in this research were applied in one of the groups, and these elements were removed in the other one. The research is qualitative, with a final quantitative component.

Results: The results show a direct relationship between the learning of computer programming by students and the aesthetic disposition mentioned in this article.

Conclusions: It is concluded that knowledge is more understandable and meaningful for the student when it is aesthetically distributed with the resources of the classroom, which facilitates storing knowledge in the long-term memory.

Funding: Universidad Tecnológica de Pereira

Keywords: meaningful learning, teaching, master class, aesthetic skills, engineering, computer programming

Resumen

Objetivo: Analizar y establecer si existe relación entre la disposición estética de elementos en el tablero y su impacto en el aprendizaje de la programación de computadores.

Metodología: Este estudio se realizó en paralelo entre dos grupos por semestre del año 2015 al 2018. Los elementos estéticos referidos en esta investigación se aplicaron en un grupo, y dichos elementos fueron removidos en el otro. La investigación

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es de carácter cualitativo, con un componente final cuantitativo.
Resultados: Los resultados evidencian una relación directa entre el aprendizaje de la programación de computadores por parte de los estudiantes y la disposición estética a la que se refiere este artículo.
Conclusiones: Se concluye que el conocimiento es más comprensible y significativo para el estudiante cuando está estéticamente distribuido con los recursos del aula, lo cual facilita la ubicación del conocimiento en la memoria a largo plazo.
Financiamiento: Universidad Tecnológica de Pereira

Palabras clave: aprendizaje significativo, enseñanza, exposición magistral, habilidades estéticas, ingeniería, programación de computadores

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Introduction

In modern times, the language of technology has become the natural language of young people. This means that university teachers must develop competencies that allow them to tune in to this natural language (Ministerio de las TIC, 2012), which enable them to respond, within a more suitable framework, to modern realities and the uncertainties generated by the knowledge of their discipline. Such competencies should be included in their professional training, which also creates a better opportunity to rely on components that strengthen motivation (Ausubel, 1963).

Engineering teachers generally do not have the required pedagogical training to deliver their knowledge in such a way that learning objectives can be efficiently achieved. However, it is essential that the engineering teachers play two roles: that of the engineer, a title earned as a result of their knowledge in the discipline; and that of the teacher, since this is the springboard to share the knowledge of the discipline (Fríes *et al.*, 2014). Reaching the learning goals through more expeditious ways will only be possible if teachers assume their role from both sides and prepare for the articulation of knowledge in the training process, with strategies that allow the students to assimilate what is imparted in the classroom (Barriga-Arceo & Hernández-Rojas, 2002).). This paper proposes a strategy

that allows, through a very simple process, the knowledge acquired by the students to be recorded in their short and long-term memory if teachers make use of the strategy as it is recommended herein, attempting to fulfill the learning objectives in an easy, understandable, and communicative way, so that the students can represent their own knowledge.

This strategy has been used at a research level in the Systems and Computer Programming program of Universidad Tecnológica de Pereira during the 1^{st} and 2^{nd} semesters of the years 2015, 2016, 2017, and 2018. Efforts have been made to be rigorous in the application of this strategy, informing the students about the process, its features, and the procedures used for assessing knowledge, as well as the qualitative and quantitative measuring tools that provide feedback throughout the experience. Both groups immersed in the research correspond to different subjects, which aims for objectivity in the analysis of results.

It is worth noting that it is not possible to design and apply a unique and perfect way to carry out a session or give a lecture, which depends on diverse factors associated with teacher-student interaction in the classroom. However, it is possible to contribute elements of judgment for the teacher to use tools that may strengthen diverse classroom strategies, including master classes (Herrán, 2009), which continues to be, as an interaction space, one of the most direct and applicable methods, without neglecting the communicative advantages of information and communication technologies (ICTs) in this context (Onrubia, 2005).

This article proposes a way to take advantage of the benefits of master class presentations by means of aesthetic skills, whose incorporation, as evidenced by the results, strengthens this learning strategy in such a way that it enables the short and long-term retention of knowledge.

Under these premises, the following research question arises: Is the incorporation of aesthetic elements on the board a determining factor in enabling a more efficient way to reach the a student's learning goals? It should be noted that some of the reflections presented here are recommendable and suggestible in direct master classes or those supported by video streaming.

This paper is one of the products of the unfunded research project "Development of a methodological model for learning imperative programming in Systems Engineering based on Meaningful Learning, Learning through Discovery, and the 4Q model of thinking preferences" [*Desarrollo de un modelo metodológico para el aprendizaje de la programación imperativa en Ingeniería de Sistemas basado en Aprendizaje Significativo, Aprendizaje por Descubrimiento y el Modelo 4Q de preferencias de pensamiento*], which was approved by the Vice-Principalship of Research, Extension, and Innovation of Universidad Tecnológica de Pereira.

THEORETICAL FRAMEWORK

The word 'strategy' is currently used in a broad and versatile way, even though, in all its possible meanings, it implies an organized and systematic set of procedures used to achieve specific

objectives accepted by a given community. It can be described qualitatively and quantitatively, and it is generally circumscribed in the world of science (Lerma-González, 2014). Alongside this word, 'methodology' implies a set of methods which have been validated, accepted, and verified for the accomplishment of particular objectives within the framework of scientific research. A simple procedure, in spite of itself, cannot be considered as a methodology (Cortés & Iglesias, 2004); it could be considered as a strategy.

In the operational domain, a strategy implies processes of information gathering, data analysis, data filtering, and validation, as well as the ordering process for later analysis, so that achieving scientific conclusions is made possible, along with eventually approaching nature, the laws that govern it, and the ways it interacts with society and individual human beings (Hernández-Sampieri *et al.*, 2006). Methodologies are based on postulates and theories that constitute their base or foundation and seek to broaden the horizons and approach the frontiers of human knowledge (Sabino, 2002). A strategy is, in simple terms, a tool used by a methodology to validate its effectiveness.

Master classes are one of the strategies that teachers can use to share disciplinary knowledge with their students, aided by a desirable systematic organization that leads to the achievement of scientific learning objectives (**?**). Although, as a general rule, master classes happen in a classroom, this is not totally true today, since virtual resources as well as modern telematic and open interactive spaces with students enable the implementation of master classes in similar (and sometimes better) conditions to those supplied in traditional face-to-face environments (Sáez-López *et al.*, 2010).

The master class (or master exposition) has been the space where the interaction between teachers and students can take place in a more direct way, since communication happens in human natural conditions, without technological mediation. Here, it is possible to perceive all the other elements that are part of human dialog, which correspond to forms of communication that, being visible, are not audible, but nevertheless strengthen the process (Trejos-Buriticá, 2013).

Training programs in engineering seek to make available to students (future engineers) the necessary tools that, based on the resources provided by the basic sciences, allow them to assimilate, model, intervene, optimize, improve, give feedback on, and modify the outside conditions under which human beings live, either natural or artificial (Blanchard, 2000). Systems engineering seeks support from new technological tools, modern advances, and electronic computational technology, in order to make said tools more optimal in their use and appropriation.

The teachers of engineering programs have been trained as engineers but not as teachers, and even though many of them have refined their teaching and learning strategies, it is worthwhile to keep in mind that their training profile is not pedagogical but engineering- centered, and this leads to the consideration that it is convenient to deepen not only their disciplinary knowledge, but also the theories, strategies, and activities that strengthen their teaching skills for the benefit of their students.

A reflection stems from the previous consideration, concerning the question of whether they are engineers-teachers, teachers-engineers, or simply both, since they carry out both tasks. The knowledge, assimilation, appropriation, application, and evaluation of learning theories, teaching strategies,

and mechanisms, as well as the modes and means of direct, indirect, synchronous, asynchronous, mediated, and non-mediated communication, are part of the reflections and practices that, in these modern times, are part of the duties of engineers, regardless of their profile, with respect to their teaching activities. To put it in other words, their teaching apostleship must be steered in the right direction, where learning, as a primary objective, justifies the presence of students in the academic scene.

These are the times when the teaching environment invites to reflect on the fact that society's constant changes and evolution, with respect to the use of technologies in general and the educational world in particular, have reinforced the perception that ICTs are necessary in basic or professional training processes (Sáez-López *et al.*, 2010). According to the standards established by the United Nations Organization for Education, Science, and Culture, it is understood that the so-called ICTs can help students get the necessary skills to become a) competent in the use of information technologies; b) searchers, analyzers, and evaluators of information; c) problem solvers and decision makers; d) creative and successful users of productivity tools; e) communicators, collaborators, publishers, and producers; and f) informed and responsible citizens capable of contributing to society (UNESCO, 2008).

There is something behind all this that, if not explicit, is there as part of the reflections. The appropriate use of ICTs forces teachers to develop certain skills which might not be present in the personal field, especially when they are digital immigrants, but it should be in the media orbit as a product of their use and interaction: the need to rely on some aesthetic considerations, skills that stand out as the corpus of this research. How does this happen? A very simple way to demonstrate this is the interactive communication that takes place through the Whatsapp service, so popular in these times.

Since communication through this app is electronic, the type of standard font used (arial or times new roman) corresponds to an absolutely legible and understandable type. Even if we were using expressive emoticons in this context, communication would be much more understandable, in comparison with the type of handwriting used by a teacher or a student. This suggests that teachers' histrionic skills, their communicative ability, knowledge, and disciplinary adequacy are not enough; it is also essential to rely on other skills to support the teaching practice.

METHODOLOGY

The strategy presented in this paper has been used in the Programming I and Programming II courses of the Systems and Computers Engineering program at Universidad Tecnológica de Pereira, during the first and second semesters of 2015, 2016, 2017, and 2018. It should be kept in mind that the content of these courses is organized by topics, and that each topic is associated with a week; four topics have been chosen as a base for experimentation and research. In the Programming I course, the content deals with functional programming and its implementation through the Scheme langua-

ge. The content of the Programming II course content corresponds to the paradigm of imperative programming and its implementation using DevC++, which corresponds to the C++ language environment in its purely imperative aspects.

Each week has three sessions, which are dedicated to each topic for its exposition, revision, appropriation, and application. The first session of each week is devoted to theoretical explanation, definition of applications, and analysis of examples. The second week is focused on reinforcing theory, reviewing applications, and analyzing further examples, one of which was completely solved by the teacher, including the corresponding IDE (Integrated Development Environment), depending on the course. The other exercises are solved by the students. In the third session, there is a quick review of the studied theory, and, for the application part, exercises are formulated as a workshop for them to be solved in the computer room with teacher accompaniment.

The two different groups of courses were developed in parallel with the purpose of making the corresponding comparative analysis, without one course affecting the development of the other. In each of them, the master class strategy had a different connotation.

With one of the groups, the master class was characterized by an intentional aesthetic use of the board, with an appropriate use of handwriting and a geometrical distribution intended to make the most of the board space, as well as a utilization of the useful area of the board based on the sequential distribution of the written text (left to right and up to down).

The drawings, diagrams, representations, and outlines were clear and artistic enough. The diagrams associated with the Cartesian plane were made with tools such as a didactic compass, a scaled rule, and a square, so that they were as meaningful as possible.

With the other group, the exposition was the opposite (intentionally), that is, good handwriting was totally absent, including some unintelligible annotations, a totally random and messy distribution and use of the board space, a complete absence of sequential order in the notes, an intentionally diffused graphic representation, lack of reference of some graphics on the Cartesian plane, and a lack of use of didactic tools that could make a clear geometry possible.

During and at the end of the master classes, the students were invited to copy in their notebooks the information presented on the board by the teacher exactly as it was written. For each of the groups in parallel, Whatsapp groups were allowed to be created separately, so that the students could expose their concerns. These groups included the teacher.

All the questions asked through the Whatsapp groups were answered, and this made it possible to monitor the questions. The midterm written evaluations were carried out in two groups in similar conditions, in close dates (normally, the difference was not greater than two days) and with very similar formulations, exercises, and approaches, so that it was possible to conduct a result that was as objective as possible, from the perspective of its approach, and keeping distance from the respective conceptual boundaries of each programming paradigm.

RESULTS

For the purpose of this analysis, the groups where the strategy described in the Methodology section was applied will be called 'Groups with Aesthetic' (G with A). In a similar way, the groups where this strategy was completely absent will be called 'Groups without Aesthetic' (G without A). Table 1 shows a summary of the students who made up the groups participating in this study.

Table 1. Students involved in the study

Year	Sem	Students		Tot
		G with A	G without A	
2015	I	22	21	43
	II	23	22	45
2016	I	23	23	46
	II	20	20	40
2017	I	19	18	37
	II	21	20	41
2018	I	21	21	42
	II	20	20	40
Total		**169**	**165**	**334**

Source: Authors.

Tables 2a and 2b show a summary of the queries carried out in person and via Whatsapp (including text, audio, video, and pictures) during the semester. To facilitate data treatment, the students' partial grades have been averaged. The specific details of each group are available for later verification.

It is worth noting that a query through Whatsapp is defined as any interaction that could be framed within one of the four categories (text, audio, picture, video).

Table 3 shows the comparative results of the quantitative valuations of the average of the midterm and final examinations for each group.

During the last week of each semester, the students were asked to anonymously write their opinions about the experience in a free and spontaneous way, focusing on those factors that they considered to be of higher importance for the development of the course, which had affected the learning process in a significant way.

Table 2a. Queries made – Groups with Aesthetic

Year	**Sem**	**In-Pers. Q.***	**Q. via Whatsapp**				**Avg**
			Txt	**Audio**	**Pict**	**Video**	
2015	I	189	19	9	5	2	224
	II	267	23	8	3	3	304
2016	I	354	27	9	3	2	395
	II	312	38	9	4	2	365
2017	I	265	36	7	3	3	314
	II	233	32	7	4	3	279
2018	I	423	42	9	5	3	482
	II	255	23	10	4	4	296
Total		**2298**	**240**	**68**	**31**	**22**	**2659**

*In-Pers. Q. = In-person Query

Source: Authors.

Table 2b. Queries made – Groups without Aesthetic

Year	Sem	In- Pers. Q.*	Q. via Whatsapp				Avg
			Txt	Audio	Pic	Video	
2015	I	47	167	39	19	85	357
	II	65	255	40	11	63	434
2016	I	87	253	31	21	62	454
	II	44	303	54	28	82	511
2017	I	36	405	62	31	52	586
	II	28	336	34	31	63	492
2018	I	36	278	38	38	74	464
	II	55	290	36	29	75	485
Total		**398**	**2287**	**334**	**208**	**556**	**3783**

*In-Pers. Q. = In-person Query

Source: Authors.

Table 3. Quantitative results - partial evaluations and final exam Source: Own elaboration

Year	Sem	G with A		G without A	
		MA	FE	MA	FE
2015	I	4,3	4,0	3,2	3,4
	II	4,2	4,5	3,1	3,5
2016	I	4,6	4,6	3,4	3,2
	II	4,4	4,6	3,3	3,2
2017	I	4,5	4,7	3,4	3,4
	II	4,2	4,3	3,1	3,3
2018	I	4,2	4,3	3,1	3,2
	II	4,1	4,2	3,0	3,1
Averages		**4,3**	**4,4**	**3,2**	**3,3**

MA = Midterm average; FE = Final Exam

Source: Authors.

Since just the most frequent factors were selected, the total of students in Table 4 does not match the total of students who participated in this study.

The two factors with the highest frequency were selected in each group, given the matching responses. For this purpose, the students were allowed to stay alone in the classroom, so that they could feel completely free; they were even allowed to talk with their classmates.

The two factors selected, given their high frequency in the students' opinions were F1+ use of aesthetics on the board, F2+ drawings and graphics that are easy to understand. On the other hand, the selected negative factors were their antipodes, that is, F1 - lack of aesthetics on the board, F2 - drawings and graphics that are hard to understand (according to the same student's opinions).

Discussion

According to the data shown in Table 1, it could be concluded that the quantity of students selected to participate in this study and the time devoted to the process are sufficient, since the process was carried out throughout eight semesters, with a population of 334 students (out of 800 students, approximately). Of this amount, about half of them were present in the research process. This makes it possible that the inferences made concerning this student population are solid enough to enrich the discussion, and that these can be extrapolated both to other courses of the same and other programs.

Table 4. Student opinions

Year	Sem	Positive Factors		Negative Factors		Tot
		F 1	F 2	F 1	F2	
2015	I	11	10	12	10	43
	II	9	11	12	9	41
2016	I	11	10	12	9	42
	II	12	8	12	8	40
2017	I	9	7	11	6	33
	II	10	9	12	7	38
2018	I	12	8	13	7	40
	II	11	9	13	7	40
Total		**85**	**72**	**97**	**63**	**317**

Source: Authors.

Tables 2a and 2b show a very interesting scene: the amount of doubts expressed by the students to their teacher was reflected, either in person or via Whatsapp, which was the only service analyzed in this study, although the use of email was also enabled but not used frequently enough so as to statistically affect the results. In so far as the amount of students' personalized queries in the G with A, it was overwhelming, since there were 2.298 queries in comparison with the 398 from G without A. It could be thought that, for the students of today, it is more difficult to express doubts through a service with which they feel more comfortable.

This supposition is confirmed by reviewing the queries made via Whatsapp, since the higher results correspond to the groups where the master class was used without an important aesthetic component on the board. The queries made by this group using text, audio, pictures, and video correspond to 2.287, 334, 208, and 556 respectively, while the queries made by the students in G with A correspond to 240, 68, 31, and 22 in the same items.

This somewhat suggests that a higher number of queries were generated when the aesthetic elements on the board were absent than when they were present, considering that the groups were selected at random. It is worth noting that, in both groups, the highest percentage of queries were made using Whatsapp, which seems to be the most utilized and comfortable service for the students.

Table 3 shows an approximation of the quantitative results of the grades collected in the written midterm evaluations. The difference is noticeable (with a value higher than 1), and it favors those stu-

dents belonging to G with A. In each item (average of midterms and average of final examinations), the quantitative advantages were always and overwhelmingly higher than in the group where the master class strategy was not based on the aesthetic use of the board. Here, it is worthwhile remembering that a great effort was made to make the written evaluations similar in their content both in form and in substance. Finally, Table 4 shows the students' opinion with respect to the most important positive factors that had favored their learning process, and the most important negative factors that had made their learning process difficult. Curiously enough, the two positive factors chosen by most students correspond to the negative factors which made their learning process difficult. According to the students, it is very important to keep the aesthetics on the board, and the drawings and graphics sufficiently didactic and understandable.

Conclusions

According to the general approach of the present study, it can be concluded that, in a computer programming course belonging to a Systems and Computer Engineering program – as evidenced in the results – master classes are strengthened if aesthetic elements are adopted for the order and presentation on the board. According to the results, this seems to be a determining factor in the learning process, since the aesthetic component depends not only on what the students write down on the notebook (students usually note down on their notebooks exactly what they see on the board) but also on what they understand from the theory. In any way, the high level of comprehension resulting from the master class through the aesthetic use of the board cannot be ignored, as well as the resulting number of doubts, and this makes the process dynamic when the aesthetic element is not present. Both forms of presentation of information have great advantages for the feedback process implied in learning.

It would be enriching to extend this study to comprise other fields and even other programs, in order to carry out a continuous analysis to compare the respective results with those obtained in this study. Once the aim of this research has been reached, it would be desirable to encourage soft skills among engineering teachers, such as appropriate distribution on the board, the use of the good handwriting, appropriate use of color markers, a good use of tools for the construction of geometric figures, good skills to draw artistically, and a good general presentation when the utilization of the Cartesian plane is required as reference.

Regarding the aim of this study, it could be argued that it has been accomplished, and that, according to the results obtained, learning from the incorporation of aesthetic elements on the board to enhance the master class was much more effective than learning based on the counterpart experience.

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