Application of an instructional model based on perceptual discrimination to teach concepts of materials and manufacturing processes in design courses

https://doi.org/10.56238/sevened2024.009-024

Ivan Mota Santos[1], Róber Dias Botelho[2] and Paulo Miranda Oliveira[3]

ABSTRACT

The objective of this work is to experiment with an instructional model based on perceptual discrimination for the teaching of concepts in design. The process of developing this model was based on the understanding of how the pedagogical relationship between teachers and design students is established in the search for expertise in the area and, with that, to propose a didactic-pedagogical model capable of assisting in the processing of information, in order to enhance the training of new professionals based on an integrated educational system. This work is part of the teaching of design and, consequently, of education. Its focus is dedicated to the use of educational technology resources in pedagogical situations within bachelor's degree courses in design. The selected starting criteria contextualize its development and implementation, in parameters recently tested and presented by the science of learning and cognitive science, with main interest in the use of perceptual discrimination. It is understood that the model can enhance the teaching of design by allowing greater dynamics, flexibility and technological integration, especially in the first years of the course; The results of experiments on laypeople with no knowledge of the subject demonstrate how successful the technology has been in this aspect. The results corroborate the idea of optimizing the process and, therefore, would be able to reduce the time needed for pedagogical fulfillment in certain phases of teaching; The results of the application in an open course applied at a distance and also used with regular course design students corroborate this point. The protocol applied favors technological advancement in the search for continuous improvement of teaching in its entirety; The modules, once built, are easy to reapply, with simple adjustments, providing the continuous evolution of the model, whether in updating content, adjusting praise and feedback, or even expanding the didactic program.

Keywords: Instructional Model, Perceptual Discrimination, Design Teaching, Experimentation.

[1] Universidade Federal de Juiz de Fora - UFJF. Doctor.
[2] Universidade Federal de Juiz de Fora - UFJF. Doctor.
[3] Universidade Federal de Juiz de Fora - UFJF. Doctor.

INTRODUCTION

EDUCATIONAL TECHNOLOGY APPLIED TO THE TEACHING OF DESIGN

This work is part of the teaching of design and, consequently, of education. Its focus is dedicated to the use of educational technology resources in pedagogical situations within bachelor's degree courses in design. The selected starting criteria contextualize its development and implementation, in parameters recently tested and presented by the science of learning and cognitive science, with main interest in the use of perceptual discrimination[4].

Perceptual discrimination is one of the most relevant techniques and theories for the science of learning, both because of the surprising results achieved quickly with students from different areas, but also because of the good theoretical structure and research models.

This experimental study is part of a large research project that is directly associated with the areas of design, education and expertise training. Still, being a vague delimitation about what was investigated, with a reasonably broad definition, connecting to this theme, we have the theory and practices of perceptual discrimination, along with investigations about the construction of expertise.

OBJECTIVES

The overall goal with the research is the experimentation of an instructional model based on perceptual discrimination for the teaching of concepts in design. The process of developing this model was based on the understanding of how the pedagogical relationship between teachers and design students is established in the search for expertise in the area and, with that, to propose a didactic-pedagogical model capable of assisting in the processing of information, to enhance the training of new professionals based on an integrated educational system.

MAIN ARGUMENT AND ASSUMPTIONS OF THE RESEARCH

The research is based on the following assumptions:

A) The teaching of design, as well as all educational and training practices, are facing unprecedented obstacles in the history of humanity (ROBINSON, 2006, 2010a and 2010b). Thus, the need for innovative, flexible, customizable instructional models are the front line for a reform, or even a revolution, in education.

B) As presented by the theory of perceptual discrimination and indicated by empirical investigations related to the subject, the brain learns automatically, assimilating information, facts, and concepts naturally and unconsciously.

[4] *The translation used by CAREY in his 2014 bestseller of the original English term, "Perceptual Learning", was adopted;*

C) The identification and discussion of the factors that define design expertise can help in the development of guidelines for the training of professionals who are better prepared for the challenges of the uncertain future job market.

D) The use of various technologies such as methods, software, models and electronic and digital equipment have proven to be interesting resources for a better learning experience, helping active, collaborative learning and teaching for understanding.

GENERAL SCOPE

For the development of the project of an educational model or technology for the design, the research was based on concepts, methods and theories from four areas of human knowledge:

1. Perceptual Discrimination
2. Science of Expertise
3. Cognitive Science and Learning Science
4. Data Analysis

The first contribution comes from the theory of perceptual discrimination, which offers the mechanisms of rapid assimilation of concepts. From the studies related to expertise in design, it is understood how to define expertise in the area and achieve it through pedagogical means. The pedagogical factors analyzed by the bias of learning science, in turn, indicate the best practices and strategies related to the cognitive and non-cognitive aspects of the teaching-learning relationship, and finally, the theory of data analysis applied to the classroom, presents organizational techniques for decision-making based on reliable data.

PERCEPTUAL DISCRIMINATION

The most appropriate technical description of the theory of perceptual discrimination, however, is directed to the researcher who organized and presented this important resource to the academic community. Gibson (1969) stated that "perceptual discrimination is a process of differentiation of distinct features of objects, permanent features of spatial layout, and invariants of events." The Stanford Encyclopedia of Philosophy presents on its official website[5] the assertion that the process involves the incredible improvement in the individual's ability to respond to the environment. In 1978, in a similar way, Westheimer stated that throughout the life of an organism, perceptual discrimination occurs successively and naturally, leading to functional and structural changes of neurons in the sensory cortex. As will be presented below, in laboratory experiments, it is more easily observed that the use of this learning instrument improves the performance in pattern recognition in interval tasks. In all the cases presented, the individual who is repeatedly exposed to

[5] https://plato.stanford.edu/entries/perceptual-learning/

stimuli and information presents an improved performance for the trained skill. Geller (2011) points out that perceptual discrimination can be defined as the process of changes induced by experience or practice in the collection of information.

Carey (2014) presents a collection of studies to reveal the idea that the brain can be understood as a pattern-recognizing "machine" and, when properly focused, can quickly deepen a person's understanding of a principle. In even more detail, Gibson (1969) informs that the three basic elements that guarantee the effective result of the practical application of the theory structured by it are:

1. The specificity of discrimination (what is learned)
2. Attention optimization (how learning occurs)
3. The increase in the economy (speed in the identification of stimuli)

METHODOLOGY

The experimental part of educational technologies are laboratory in nature, taking place in controlled or partially controlled environments. The practices and use of technology "at a distance" and in some cases was used in order to mimic learning situations in MOOCs[6], for example. The distinction between students, professionals and laypeople in relation to the theme of the experiments establishes a "control group" effect in all the cases presented. Many of them also offered only part of the stimuli put to the test in the training protocols. This procedure allows the researcher to accurately verify the impact of the deliberate practice protocol training on the participants' performance.

The pre-tests established the initial parameters of the experimental groups and delimited their diversity, while the longitudinal character of the experiments evaluates the evolution of the information collected over time, i.e., measuring the use and impact of the training (performance) and also measuring the variations in the measurement of perception in subjective aspects such as motivation and academic mentality. The indicators of motivation and academic mentality used are derived from references presented in MOTA-SANTOS, I.; LANA, S. (2019b) and Santos and Lana (2020) respectively, with 5 statements that are placed as a self-assessment system on a scale of agreement. One of the indicators of motivation also concerns the learning objectives, which is one of the most important elements for the success of any pedagogical project. In addition to this indicator, some modules carry out a self-assessment of the specific objectives of each content, in which participants answer directly with 'yes', 'no' or 'maybe' about the ability to perform tasks or recognize certain contents. In some of the modules, only a few participants received stimuli related to the construction of an academic growth mentality in relation to the themes. In these cases, the objective was to measure the impact of this procedure on the overall improvement of performance results, as

[6] MOOCS - Massive Online Open Courses - "Cursos Online, Abertos e Massivos"

well as on the ability to positively alter this non-cognitive factor of pedagogy in design. Finally, participants were also asked to confirm whether they performed other tasks simultaneously with the study sessions, with the goal of verifying the impact of multitasking on performance outcomes.

The trainings were basically applied in two modalities: free practice and formatted and identical execution for all participants. The objective was to verify whether the number of times the individual was exposed to training directly affected the general indicators, whether cognitive or not. In some of the cases, the indicators mentioned above were also included in the training sessions, so that the capacity for longitudinal changes in the execution of the tasks could be ascertained. The final evaluation forms served as a comparative basis to measure the changes obtained in performance, academic mentality, motivation levels and other specific indicators. The details and variations in each of the experiments conducted throughout this work will be presented.

A deliberate practice protocol-building approach was adopted for recognition training and utilization of design concepts within the first two years of the regular course. In addition, a form of automatic correction of evaluations was structured and, in some cases, also in the training of placing praise written according to the guidelines found in the previous chapters, as well as feedback with the correct answers. In specific didactic situations, in addition to the correct answer, some kind of stimulus related to self-determination or academic mentality was added. The compliments, when used in the automatic answers to the forms, were always intended for the effort to gain autonomy and competence, in addition to thanks for the time dedicated to the acquisition of that knowledge.

MATERIALS IN DESIGN WORKSHOP

The protocol of deliberate practice[7] applied in a workshop to teach the concepts of materials for design was constituted in three major stages or modules. The first stage concerns an initial assessment dedicated to the measurement of content knowledge, with 65 points or questions, in addition to a subjective self-assessment of questions related to motivation, which are structured in 5 indicators. In addition to these motivation indicators, two indicators are directly linked to learning objectives. Regarding the motivation indicators, five statements were selected that, when presented to the participants, allow self-assessment on a Likert scale (1932)[8] ranging from 1 to 5, with 1 being total agreement, three being neutral, reaching 5 level of total disagreement. Regarding the learning objectives, the questions were asked with yes and no answers. They were structured in a very direct

[7] Concept, which refers to repetitive training dedicated to a theme or activity. It aims to gain expertise quickly and efficiently, and structures many mechanisms of perceptual discrimination. (ERICSSON, 1999)
[8] A type of psychometric response scale commonly used in questionnaires, and is the most commonly used scale in opinion polls. When answering a questionnaire based on this scale, respondents specify their level of agreement with a statement. (LIKERT, 1932)

way, confronting the participants if they knew how to point out certain contents or differentiate types of materials, for example, and totaled 20 points.

The second phase of experimentation concerns training. In this specific case, the trainings were carried out in four sections divided by themes: introductory aspects of materials with 23 questions, aspects of production with 19 questions, recent developments in materials with 15 questions and, finally, environmental impact in the production of materials with 8 questions. It should be noted that the training offers participants the opportunity to review the 65 questions that are the performance metrics presented in the initial evaluation and that will also be part of the final evaluation. In addition, each of the 4 training modules offers participants the opportunity to report on whether they multitask during the study sessions. In this first experiment, only closed multiple-choice questions were used. Most of them presented as options the material groups or specific types of subcategories within the major material groups. In addition, the other questions presented statements about materials that allowed the choice of true or false. During all trainings, regardless of the right or wrong, each participant had to see the correct answer to the question before being able to move on. The final evaluation, in turn, which is the last stage of the experiment, has an identical structure to the initial evaluation, with the same metrics of performance, motivation and learning objectives. These modules were structured using digital form-building tools. These tools allow the quick collection and organization of data, in addition to the possibility of using data exported in "CSV" format to spreadsheets that allow for different analysis approaches.

After carrying out the experiment related to materials concepts, which was configured as an introductory module for the initial testing of the protocol, the manufacturing process modules were developed. These, despite being broader and more in-depth, maintained the basic structure of initial forms, trainings and final forms. In addition, the modules allowed a longitudinal verification of learning and tested different variables, such as the comparison of different visual stimuli containing the same information.

MANUFACTURING PROCESS MODULES FOR DESIGNERS

The modules teaching manufacturing process concepts to designers is a much broader experiment than the previous experiment. Although the structure is similar, the amount and variety of content is much greater, with six different modules totaling 18 stages in total. Each module had an initial evaluation form, a training form that could be completed numerous times, and finally, a final general evaluation form.

The first module referred to the categories of industrial manufacturing processes as cited in Thompson (2007). The second module concerns the identification of 18 different forming processes. The third module deals with the classifications of industrial processes, and the fourth concerns the subcategories of manufacturing processes as indicated in Lefteri (2009). As a highlight in this application, we have the execution of the fourth, fifth and sixth modules that deal with the precise recognition of industrial processes. The three modules have identical structures in their initial assessment, in their training, and in their final assessment. However, the highlight is the stimuli used, as the first of them uses texts and descriptions about industrial processes; the second presents images of products produced with the processes and finally, the third presents organizational charts and explanatory images of the operation of the processes. Thus, the creation of these three modules aims to measure the impact of different stimuli on the assimilation of concepts in design, in this case the recognition and memorization of 20 different industrial manufacturing processes.

Regardless of the contents for each module, the first form made the initial measurement of the participants' knowledge on the subject, also allows self-assessment and measurement of motivation. In addition, the form also offered the evaluation of the subjects' position on the learning objectives. In the training, in turn, in addition to measuring scores or performance, the subjects were also asked to report the performance of other activities and multitasking during the study sessions, as in the previous experiment. The final modules, on the other hand, measure, in addition to the performance gain, all the requirements contained in the initial assessment, allowing the comparison of motivation indicators and learning objectives.

GENERAL SUMMARY OF THE STRUCTURE OF THE EXPERIMENTS

For a more direct visualization of the structuring indicators of the protocols, a table was developed. In addition to the performance indicators, their types and quantity, the indicators of motivation, academic mentality, learning objectives, and indicators of multitasking were quantified for each experiment performed (TAB.1).

TAB 1. Basic structuring of the experiments.

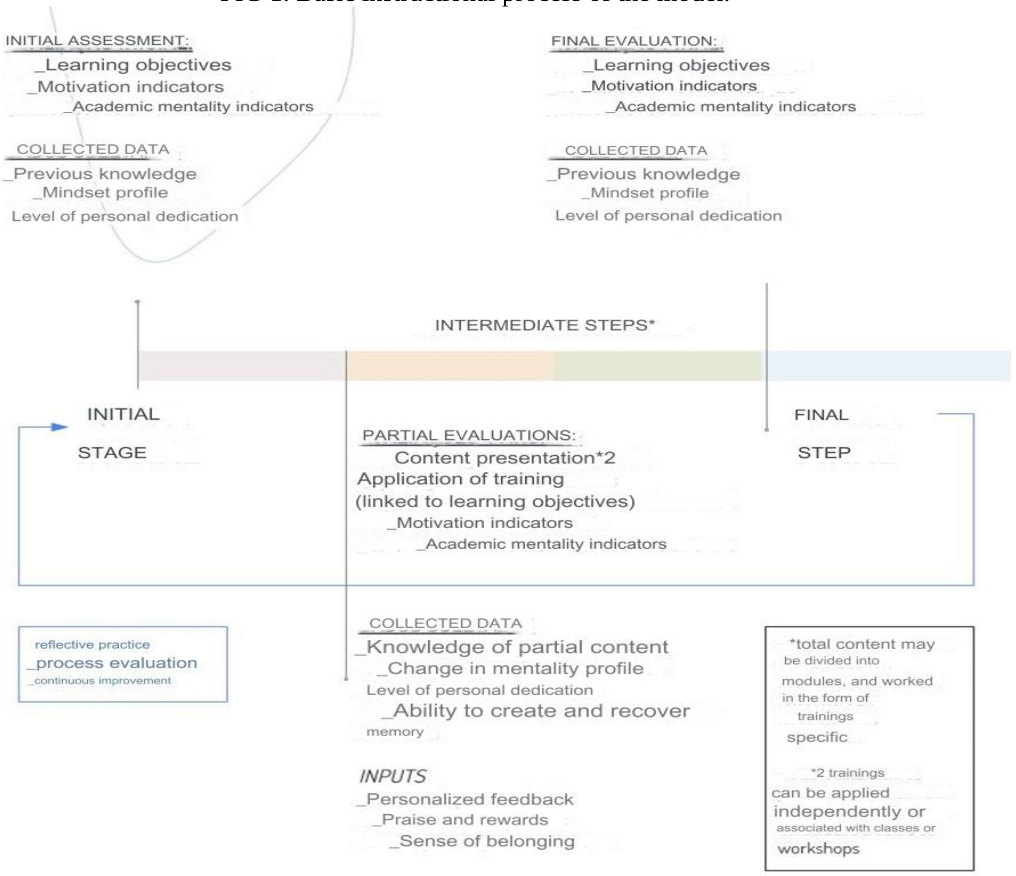
EXPERIMENTS	PERFORMANCE INDICATORS		INDICATORS MOTIVATION	INDICATORS ACADEMIC MINDSET	OBJECTIVES APPRENTICE SHIP	INDICATORS MULTITASKING
	CONCEPTS	KIND				
MATERIALS	65	VF ME	5	1	20	2
PROCESSES	119	VF ME	5	1	1	2
CLASSROOM DISCIPLINE	84	VF ME QA QR	–	–	–	–
WHAT 3D	33	ME QA QR EP	5	5	1	2

CAPTION: VF - True or False | ME - Multiple Choice | QA - Open Questions | QR - Reflective Questions | EP - Practical Exercises

Source: From the author, 2024.

The procedures of the instructional model, organized by stages in a simplified version, are illustrated in Figure 1. In it, it is possible to see the relationship of the initial stage with the training sessions and with the final evaluation, both with regard to the indicators mentioned above, as well as in relation to the data collected and possibilities of action of the instructor/teacher (*Inputs*).

FIG 1. Basic instructional process of the model.



Source: By the author, 2024.

SAMPLING

General Profile of Participants

During the initial questionnaires, questions were asked to understand basic information about the participants. Regarding design students and professionals, the reported ages range from 21 years to 47 years old, however, the largest group of participants, 18 of the 49, are between 22 and 24 years old, and 30 of the participants are between 21 and 28 years old. They represent 6 different design courses.

In the case of design teachers, on the other hand, the age ranged from 28 to 67 years and the average age of the 21 participants is around 45 years. The professors participating in the research represent seven different institutions, one of them being an international university. Of the 21 professors, more than 50% have a doctorate and almost 40% have a master's degree, and 81% of them have a background in design in their undergraduate studies and have been graduated for more than 10 years. Regarding teaching practice, 30% of the participants have been teaching for more than 20 years, 35% for more than 10 years, and 30% have up to 5 years in the classroom.

All participants who answered the questionnaire are Brazilian. In the group of design students and professionals, only 2% of the population had a master's or doctorate degree, and 14% had a postgraduate degree. Of the rest, just over 80% are design students or recent graduates.

When we evaluate the participants of the initial experiments and the protocols applied in didactic situations, we have the totality of students or professionals who have recently graduated from the undergraduate program. The participants are mostly students from Brazilian universities, whether they are students of design or other courses. We also found the participation of professionals from different areas, as well as exchange students from universities in other countries.

TAB 2. Total sampling and distribution by activities.

ACTIVITIES AND PARTICIPANTS	Types of Subjects	Quantity	Total
Applied Model	Students	106	136
	Lay	30	

Source: By the author, 2024.

RESULTS OF THE APPLICATION OF THE MODEL

The protocol model of deliberate practice developed based on the concepts and implications presented by Mota-Santos and Lana (2019a), served as the basis for reaching this point of the research. Then, extrapolations in variables such as stimuli, in addition to the expansion of the longitudinal character of tests will be presented in the modules related to industrial manufacturing processes. Another aspect that makes the model unique is the measurement of indicators of non-cognitive pedagogical factors presented by Santos and Lana (2019b) and (2020).

METHOD APPLIED TO MATERIAL CONCEPTS

The training modules applied to the concepts of materials in the lay group, which had 7 participants, obtained an initial average of 44 points out of 65 offered. In the case of the 24 design students participating in the other group studied, in turn, the initial average was 46.04 points out of 65. This result is noteworthy, because the design students were already taking or had attended at least one materials course, which would suggest a much greater difference in this result. Thus, it can be inferred that the questions presented are supposedly very basic, linked to superficial knowledge of the groups of materials and their characteristics. The results described are summarized in Tables 16 and 17.

Most of the indicators of intrinsic motivation of the laity were associated with positions of partial and total agreement, and only the indicator linked to the level of knowledge in relation to the theme remained neutral in this initial phase. The motivation indicators of design students were also maintained on the concordance scale.

TAB 3. Synthetic results of the materials experiment: laymen.

PERFORMANCE INDICATORS	INITIAL ASSESSMENT	FINAL EVALUATION	TRAINING	
–			REPETITIONS	OVERALL AVERAGE
CONTENT	44/65	62/65	19	56,75
MOTIVATION	1,94	1,56		
LEARNING OBJECTIVES	32,7%	93,3%		

MOTIVATION SCALE: Scale: 1.Very Good, 2.Good, 3.Fair, 4.Poor, 5.Very Poor
Source: By the author, 2024.

The overall average of points obtained in relation to the introductory training was 19.6 out of 23 points, and, among those offered in the productive aspects, the average was 16.4 out of 19 possible points. On recent material developments of 13.75 out of 15 possible, and in the training module on environmental impacts, the average was 7 points out of 8 possible.

The final average obtained by the lay participants in the 65 possible points of the last global evaluation of the course was 62 points, a considerable increase in relation to the 44 average points of the initial evaluation. The final average obtained by the design student participants also increased, reaching 56.29 points out of 65 offered. Although this number showed a considerable improvement, more than 20 points in the initial average, the result was below the final result obtained by the lay participants. As a related indicator, the motivation factor of design students can be reported. In the case of design students, once again the result was surprising. The motivation indicators remained at the level of agreement for the most part, but worsened in relation to the initial evaluation in almost all indicators. In the case of lay people, on the other hand, the motivation indicators also improved, with four of the five indicators tending to be in full agreement with the statements presented. The level of interest in acquiring knowledge can be understood as a possible explanation for the recorded phenomenon. The lay people volunteered to carry out the modules in MOOC format offered in the university's program. Design students, on the other hand, had the modules inserted as training exercises during the regular completion of course subjects. Many of them reported feeling an excess of curricular activities during the period.

TAB 4. Synthetic results of the materials experiment: students.

PERFORMANCE INDICATORS	**INITIAL ASSESSMENT**	**FINAL EVALUATION**	**TRAINING**	
–			**REPETITIONS**	**OVERALL AVERAGE**
CONTENT	46,04/65	56,29/65	125	58,44
MOTIVATION	2,24	2,1		
LEARNING OBJECTIVES	28,8%	49,1%		

MOTIVATION SCALE: Scale: 1.Very Good, 2.Good, 3.Fair, 4.Poor, 5.Very Poor
Source: By the author, 2024.

METHOD APPLIED TO MANUFACTURING PROCESS CONCEPTS

The first module of this large experiment, linked to industrial manufacturing processes for designers, had 25 questions in its initial form. The initial average obtained by the laity was 8 points and 8.04 for the design students. It should be noted that once again, we have a similar initial note between the groups. Despite being a different phenomenon from what was predicted, which would place design students with a higher initial grade, these occurrences do not take away from the measurement merit of the research or the model used.

On motivational indicators, design students will tend to agree, but close to neutrality on almost all indicators. Unlike the lay people, who showed that they were much more motivated with the execution of the course and only tended to neutrality in relation to the indicator that refers to the level of knowledge on the subject. Thus, we have exactly the same result as the previous experiment for the initial phase, both in relation to performance indicators and non-cognitive factors linked to motivation. The indicator referring to the knowledge of the theme is in line with the answers of the lay participants about the learning objectives; in which they indicated in their entirety or lack knowledge of the contents presented in the course. In the case of design students, many indicated that they may have been able to point out part of the course content correctly, which would perhaps justify the demotivation registered.

In the training form, the design students performed 84 sessions and increased their overall average performance to 17 points, while the lay people performed five sessions and increased their performance to 22 points out of a possible 25. In the execution of the final form of the polymer module, the design students achieved an average of 18.33 points and the lay people achieved an average of 24 points out of a possible 25. The motivation indicators of design students have improved, with the exception of the indicator that concerns the level of knowledge. The laity, on the other hand, had a significant improvement in all motivational indicators, with the exception of the statement regarding the level of interest in the topic. This result was further reinforced, with the learning objective gauges that were mostly negative or uncertain for design students and, unlike for laypeople, showed significant improvements.

This same pattern was repeated in the second module of the course, since the initial average of the 18 possible points in the second module was 13.85 for design students and only 7.50 for laypeople. The motivational indicators also show the same type of reaction of the participants, with the design students showing agreement with the statements but tending close to neutrality, while the lay people are also in the agreement zone but tending, in most indicators, to total agreement. After completing the training, the design students were able to improve their performance by reaching 16.46 points on average out of a possible 18. Otherwise, the lay participants, surprisingly, improved their performance to 17.40 points. Also, as we saw in the previous module, the motivational indicators for laypeople also showed improvements, while the motivational indicators for design students remained stable.

In the third module of the industrial processes course, the design students totaled an average of 11.57 points out of a possible 16 and the lay people in turn got only 7.29 points. After the training, the design students improved their performance to 15.19 points and the lay people got 16 points, that is, all the participants in this group got all the questions of the final module right. The motivational indicators reflected this improvement in performance and, although the indicators of the design students remained practically stable, the motivation indicators of the lay participants improved a lot. It also includes the indicator that relates to learning objectives.

On this issue, the two questions that directly address and gain knowledge after the training, was practically unanimous in its positivity for the lay participants. On the other hand, for design students it was predominantly dubious.

Despite the relevance of the data presented so far, the main investigative focus of the industrial process modules concerns the modules that present the 20 manufacturing processes repeated three times in the course. With stimuli of different natures, such as: the descriptive text, the image of products made in specific processes, or even the image that represents all stages of the production process. In the initial module in which the protocol was assembled with textual descriptions, the design students were able to improve the initial performance from 14.88 points of overall average to 18.04. In the case of lay people, the initial performance of 10.67 points was increased to an astonishing 19.4 points of final average. In the next module, in which textual descriptions were replaced by images of products manufactured with the processes to be learned, the design students also improved their performance from 17.88 points out of a possible 20 to 19.45. The lay participants, in turn, went from 13.20 points of initial average to 19.60 points in the final form of this module.

The last comparative stimulus module, on the other hand, had representative images of each stage of the manufacturing processes in illustrations or infographics and, for design students, represented an improvement from 18.7 points in the overall average in the initial evaluation to 19.32 points in the final average. The other participants who started with a much lower average of 10.80 points achieved a significant performance improvement reaching an average of 19.4 points.

TAB 5. Synthetic results of the manufacturing process experiment: layman.

PERFORMANCE INDICATORS	INITIAL ASSESSMENT	FINAL EVALUATION	TRAINING	
–	–	–	REPETITIONS	OVERALL AVERAGE
MODULE 1	8/25	24/25	5	22/25
MODULE 2	7,5/18	17,4/18	5	11/18
MODULE 3	7,29/16	16/16	4	10/16
MODULE 4	10,67/20	19,4/20	4	15/20
MODULE 5	13,2/20	19,6/20	4	14/20
MODULE 6	10,8/20	19,4/20	4	14/20

Source: By the author, 2024.

Although all the trainings showed positive results in performance, for both categories of participants, the results of the laypeople show the power of this tool. Quickly, in minutes, the protocol proves to be able to equate totally unmarried individuals with beginner designers. In addition, the indicators of non-cognitive factors linked to student motivation were also able to reliably represent the reaction to learning outcomes. Together, the two indicators can be an essential tool for teachers to conduct courses with much higher levels of professional training. All reported data were organized in TAB 5 for laypeople, and in TAB 6 for design students.

TAB 6. Synthetic Results of the Manufacturing Process Experiment: Design Students

PERFORMANCE INDICATORS	INITIAL ASSESSMENT	FINAL EVALUATION	TRAINING	
–	–	–	REPETITIONS	OVERALL AVERAGE
MODULE 1	8,04/24	18,33/24	84	17/24
MODULE 2	13,85/18	16,46/18	50	17/18
MODULE 3	11,57/16	15,19/16	32	14/16
MODULE 4	14,88/20	18,04/20	98	18/20
MODULE 5	17,88/20	19,45/20	70	19,42/20
MODULE 6	18,7/20	19,32/20	77	18/20

Source: By the author, 2024.

METHOD APPLIED TO CLASSROOM ASSESSMENTS

In the application of the protocols in discipline evaluations related to materials and manufacturing processes for designers, the results were considered very good. Regarding the evaluation of polymeric materials, the initial average obtained by the students before the training was 14 out of 24 possible points. With the execution of 224 training sessions of the 25 students, the average rose in the final evaluation, to 22 points out of the same 24 possible. In the training, 15 questions were offered for review and the average of the students was 14 points in general. It is noted that, although the training does not bring all the evaluation questions for review and training, the recapitulation of the concepts apparently helps in the retrieval of other questions and/or information, improving the overall performance.

In the protocol carried out physically, on paper forms, and referring to metallic materials, the initial average of the students was 18 points to 24 possible points. The same 25 students freely performed 119 training sessions and totaled an average of 14 points for the 15 offered in the training. As a result, the students improved their performance in this evaluation as well, and managed to achieve an average of 23 points out of a possible 24 in the post-training evaluation.

In the module dedicated to ceramic materials, and natural materials, the students achieved an average of 16 points out of a possible 24 in the initial evaluation. In the trainings that contained 9 questions, the students were able to achieve the overall average of 8 points, repeating the training 102 times. As a consequence, they improve their performance to 21 points out of a possible 24 in the final evaluation on the subject.

In the modules dedicated to the understanding of composite materials, which did not contain an initial evaluation, students were exposed to the opportunity for free training, for two weeks prior to the execution of the test, with 4 days of mandatory spacing of the evaluation. The form contained open questions to train the concepts and, of the 25 students, performed 64 repetitions. Subsequently, divided into two groups, they were invited to take a test that contained 12 questions. The mean score in the first group was 8 points and in the second group was 7 points. It can be seen that in addition to the execution in a much smaller number of training sessions, apparently, the slower and cognitively more demanding training with open questions, did not result in a performance of the same level as the previous trainings.

In the execution of the global exams, which measured the assimilation of the concepts during the semester period, the class was also divided into two groups that performed an evaluation of 80 points. All these concepts and questions were identical to those posed in previous evaluations. The first group obtained an average of 59 points and the second group an average of 57 points in this evaluation.

APPLICATIONS OF THE METHOD IN COURSES AND WORKSHOPS

The first relevant aspect to be pointed out as conclusive within the results presented is the fact that in all modules and experiments, all individuals showed performance improvements in cognitive indicators. In some modes or courses, some performance indicators managed to increase by more than 60%, which proves the efficiency of the model used. Regarding the objective of positioning the method for gaining expertise in concepts in the first years of the design course, the experiment carried out with lay individuals proved to be fundamental. The results presented in laypeople's performance gains were relevant, including those referring to the indicators of non-cognitive pedagogical factors. The modules proved that with minutes dedicated to correctly structured training, it is possible to match the performance performance of a layman audio student in the first years of the regular course. This discovery paves the way for the use of these protocols so that students can quickly gain autonomy. Thus, being able to use the basic concepts of design in a more assertive way in the execution of projects and using the remaining time that was optimized using these trainings to seek experience in problem solving in design practice.

The training structured in a protocol way, such as initial and final evaluation points, also allowed the correct structuring of corrections, feedback and praise that help students both in the acquisition of new concepts, as well as in the improvement of self-determination, motivation and academic growth mindset indicators. All these performance factors are also added to the speed gain in the execution of these tasks, that is, in the recognition of concepts and stimuli, in their use for categorization for justification and even for the elaboration of faster solutions. Speed gain is an important mechanism within cognitive studies, especially related to perceptual discrimination. As mentioned in other studies, the design students already performed the activities in a more agile way than the lay people, however, it was noted that both types of participants were able to improve their performance regarding the time needed to perform the tasks.

TAB 7. Synthetic results of the experiment in classroom assessments.

PERFORMANCE INDICATORS	INITIAL ASSESSMENT	FINAL EVALUATION	TRAINING	
_	_	_	REPETITIONS	OVERALL AVERAGE
POLYMERS	14/24	22/24	224	14/15
METALLIC MATERIALS	18/24	23/24	119	14/15
CERAMIC & NATURAL MATERIALS	16/24	21/24	102	8/9
COMPOSITE MATERIALS	_	7,5/12	64	_
GLOBAL	_	_	_	58/80

Source: By the author, 2024.

CONCLUSIONS

To demonstrate the validity of the proposed research, the expected results were extracted from two questions that Moreira and Caleffe (2008) present as crucial to evaluate and clarify the purpose of a research situated in the area of teaching, namely:

- It is understood that the model can enhance the teaching of design by allowing greater dynamics, flexibility, and technological integration, especially in the first years of the course; The results of experiments on laypeople with no knowledge of the subject demonstrate how successful the technology has been in this aspect. (Paragraphs 4.2 and 4.3)
- The results corroborate the idea of optimizing the process and, therefore, would be able to reduce the time needed for pedagogical fulfillment in certain phases of teaching; the results of the application in an open course applied at a distance and also used with regular course design students corroborate this point (Item 4.3)
- The protocol applied favors technological advancement in the search for continuous improvement of teaching in its entirety; The modules, once built, are easy to reapply, with simple adjustments, providing the continuous evolution of the model, whether in updating content, adjusting praise and feedback, or even expanding the didactic program.

- The results emphasize the need for an awakening of the educational system to the integrated use of the technological set in which society finds itself, for use in the classroom, in order to collect educational data that can support pedagogical decisions; The experiments carried out physically, on paper, proved to be slower and more inefficient, both for the students and for the researcher. The forms, in turn, were filled out quickly, on cell phones, tablets, computers, in order to adapt to the routine and type of access available to each participant.

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