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Parametric Design: Measuring Learning States

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Abstract: Project teaching and learning comprises properties, strategies and procedures that currently involve computational thinking and logical reasoning. In general, this problem arises from the possibilities offered by the new software and the increase of the level of dominion of the project by the designer. In this context, this study aims to estimate how much the student profile contemporary of architecture is motivated and engaged in learning new project processes that use computational reasoning and logical reasoning, characteristic of parametric design. Methodologically, the research is based on the theory of flow, presents results of an investigation of engagement and learning of students of a school of Architecture and Urbanism in Brazil, referring to the themes and uses of parametric drawing. This study contributed to the practice and use of parametric design in the educational environment, besides allowing the integration of computational thinking in the creative process of the project.

Key words: Parametric design, project processes, learning, computational thinking.

1. Introduction

Currently, project teaching especially in Architecture, Engineering and Design schools comprises properties, strategies and procedures that involve computational thinking and logical reasoning. In general, problems arise through possibilities offered by the new software and increase the level of the project's domain by the designer, through programming in user-friendly interfaces, favoring an exploration beyond the representation and expression of ideas on paper [1, 2].

In the context of the teaching of Architecture, essentially in architectural projects, it is well known that computational thinking is revolutionizing the daily life of these academics. Educators and students are using these innovative design processes, not only for representation, but as a generative tool, capable of generating complex, optimized forms and with the ability to evaluate a diversity of performance resources [3]. For some years now, this programming teaching for architects and urbanists has introduced computational techniques to generate and control geometric shapes. Precursor models include the use of programming languages for the development of computational geometry controlled by parameters [4, 5].

However, in the course of the 21st century the terms modeling and design parametric have become prominent within architectural project processes. However, the teaching of parametric design in universities is associated with the development of visual programming environments integrated with parametric modeling software, such as the Grasshopper plug-in for Rhinoceros 3D from McNeel (2007) and the Dynamo for Revit from Autodesk (2011). In this way, the visual programming instituted a dynamic and friendlier interface for the use and control of information by the designer [6, 7].

With these technological advances in the areas of Architecture, Engineering and Design, emerged the computational thinking that is a determinant method for solving a computational problem, and is being widely used in Parametric Design, with processes of algorithmic routines, which by means of software of

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programming script it is possible to create a certain procedure, to solve a complex solution [8].

Thus, an algorithm is a logical procedure with finite and well-established steps, to be executed within a certain period of time. After the beginning of the computer age the algorithms began to be used in a constant way, with the purpose of solving procedures and situations of high complexity, hitherto unimaginable for man [9].

For the process of Computer-Aided Design (CAD), the use of software and computers are essential for the development of the project. The parametric design refers to the modeling of a particular architectural model or object where it is controlled by algorithmic routines developed by particular software with parameter modeling script. Thus, this set of techniques and relationships is known as Parametrization. For a Parametric Project it is not the idea to create the shape that is taken into account, but to generate the shape, by means of a combination of parameters which was assigned to the project generating a complex shape and of easy manipulation of its values [10].

Parametric design distinguishes itself in two principles: the first consists of a group of geometric components that contain properties that can change their parameters or simply properties of fixed values. The second principle dwells on the process that is used of the geometric components to take a malleable mode [11]. Therefore, it can be said that the parametric design process is a formal investigation process that uses different variables to generate a model, and may or may not generate a complex result. One of the main premises of parametric design is to declare its parameters, rather than searching for its shape [12].

Thus, the relationship between the various available parametric manipulations software makes it easy for designers to modify parameters by rapidly changing two-dimensional and three-dimensional models, making it a powerful tool for creating and modifying digital models in the Architect and Urbanist profession [7].

In this context, technologies help in the exploration of formal design ideas, improving and integrating through information modeling. With the exploration of these technologies over the last decades, it has brought about changes in production and architectural teaching provided by new work and teaching/learning methodologies, such as information modeling, construction, parameterization, fabrication and prototyping tools [11].

In addition, with the teaching and inclusion of digital tools in Architecture faculties, the practice and use of complex architectural shape became more common. This evolution is mainly due to the emphasis of methodologies applied in the teaching of digital tools, which allow the integration of computational processes [13].

That said the Contemporary Architect must be able to produce works adaptable to any environment and with constant change, for this the use of computational thinking facilitates the creation and alteration of projects [14]. In the following text, the commentary on this generation of Architects is exposed.

"The new generation of architects must be able to develop designs that are adaptable to a continuously changing urban environment, and programming may play an important role in modeling these concepts to develop design through conditional dependencies. In other words, contemporary, architecture is fundamentally about relationships, and state of the art construction is characterized by the use of expensive materials produced with great accuracy, frequently through automated processes. A new generation of CAD software is being currently developed to respond to these new requirements." [14].

Thus, the synergy between the designer conception and the diverse digital technologies available today is transforming the way to create and do Architecture in the contemporary era. Consequently, processes and methods of expression and representation of architectural projects have flourished and found in the present era vast methodological resources, management tools, management and optimization in the project processes. All this, due to the technological innovations such as the improvement of graphic software, both 2D representation, 3D modeling, construction information modeling and visual programming scripts, consolidated in the digital medium as a tool to aid in the architectural design [15].

In this context, we are witnessing a growing progress in the production, analysis and simulation of complex and variable models generated in a computational environment, influencing the insertion of new teaching methodologies in classrooms, stimulating individual and collective learning. Thus the problem of this study arose in estimating how the profile of the contemporary student of architecture is motivated and engaged in learning new design processes that apply computational thinking and logical reasoning, characteristic of parametric design. Therefore, the objective of the research is to point out the moments of the teaching of parametric design that the students most engaged with and consequently more absorbed the learning during the project process, based on flow theory.

1.1 Theory of Flow

The flow theory was developed by the Hungarian psychologist Mihaly Csikszentmihalyi (started in the 1970s), where he researched the motives that lead people to a state of mind of full bliss, ecstasy. At such a level of concentration that all else disappears where the sense of time itself is distorted. He called this state of mind "flow state". During his research at the University of Chicago in the United States (1970s), Csikszentmihalyi developed the Experience Sampling Method (ESM) research tool to understand at different times of the day, what people were doing, where and who they were with and what they were thinking, in a numerical scale what was their degree of happiness, concentration, motivation and self-esteem. Through a Pager (programmed clock), the subjects received a signal at alternate times and had to register in what situation they were, to then classify their state happiness, concentration, motivation and self-esteem [16, 17].

Consequently, by associating flow theory with learning, it can thus relate involvement at a specific moment in a particular activity that leads the learner to a high level of concentration and motivation. Being that this process happens naturally, regardless of activity, what makes it go into "flow State" is the engagement or immersion the task in question.

The most important processes to better understand this phenomenon of engagement are: the skills needed to perform the activity and the difficulty of the proposed challenge, where both need to be in a perfect balance to reach the "flow State" [16], this process is represented in Fig. 1.

That way, depending on the skill levels and difficulty of the challenges, the people may be in different mental states. Apathy is the worst state, where there is no challenge and no skill to test. The opposite is exactly the state of flow, where all abilities are put at the service of a challenge by being able to perform. Therefore, when one has the first contact with an activity normally the subject is in a

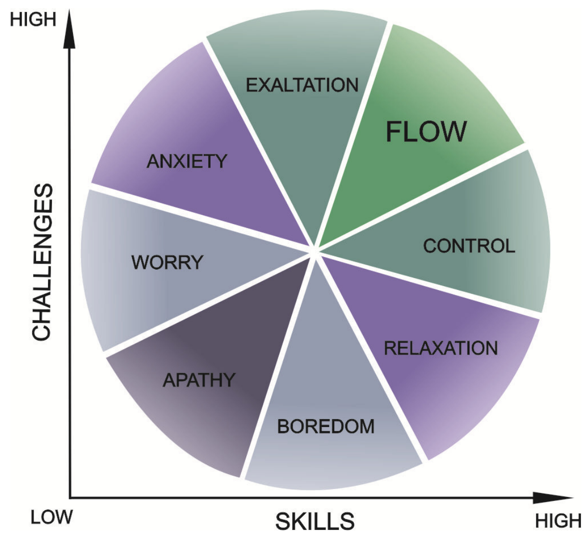


Fig. 1 Process graph skills challenges of flow theory.

middle ground, between anxiety and relaxation. Depending on the levels of challenge and skill imposed by the activity, the subject can enter into flow when it can accomplish the task with satisfaction, or come to have apathy for the activity, when their skill is insufficient to impose challenge or the challenge is insufficient to of skill [17].

2. Methodological Procedure

Methodologically, this study used the ESM research tool associated with Participant Observation (OP) method which is an immersive and ethnographic method to understand situations and behaviors through the experience of participation of members in an activity, context, culture or subculture [18]. Thus, the researcher infiltrated the content along with the research participants, in order to achieve the research objective.

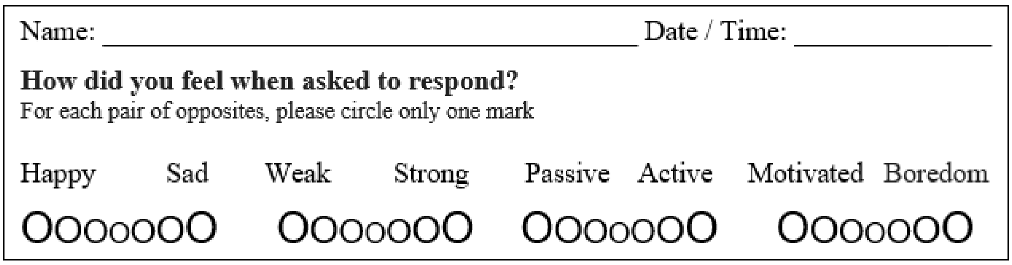
To that end, the definition of Engagement in this research is associated with flow theory, measuring students' motivation and dedication indexes during the construction of their knowledge, especially learning the parametric design process.

The methodological procedures of the research were applied in a course of the School of Architecture and Urbanism of the Faculdade Meridional (IMED) Passo Fundo, RS, Brazil, being the discipline of Digital Fabrication and Rapid Prototyping following a syllabus with theoretical and practical content of the teaching of parametric design, based on active student-focused learning methodologies such as Project Based Learning (PjBL), Time Based Learning (TBL) and Gamification of Teaching. Thus, the research was conducted in the period from August to September 2018, with a total of 45 students that were configured the population of students enrolled in the course, divided into two classes: 1st class with 11 students comprising 24.44% and 2nd class with 34 students corresponding to 75.56% of the population. Thus, the methods were monitored and applied in both classes, but the 1st class was chosen as sampling of this research.

In order to collect data, the ESM instrument (Fig. 2) was used, collecting individually on printed paper, on average every thirty minutes from the beginning to the end of each class, in order to detect the means of the Engagement indexes of the students according to the flow theory. Therefore, a total of 42 moments were collected totaling 390 ESM instruments.

In this way, the students answered the ESM instruments in four situations related to the flow theory on a scale of opposites Happy (-3)/Sad (+3), Weak (-3)/Strong (+3), Passive (-3)/Active (+3) and Motivated (-3)/Boredom (+3), in this order, configuring the four channels.

Channel C1 (Apathetic) is configured with response situations between; Weak (-1 to -3), Sad (+1 to +3), Passive (-1 to -3) and Boredom (+1 to +3). Channel C2 (Anxious) sets up with response situations between; Motivated (-1 to -3), Active (+1 to +3), Strong (+1 to +3) and Happy (-1 to -3). The C3 channel is configured with response situations between; Strong (+1 to +3), Happy (-1 to -3), Passive (-1 to -3) and Boredom (+1 to +3). The channel C4 (Flow) sets up with response situations between; Strong (+1 to +3), Happy (-1 to -3), Motivated (-1 to -3) and Active (+1 to +3), represented in Fig. 3.


Name: ______________________ Date / Time: __________

How did you feel when asked to respond?
For each pair of opposites, please circle only one mark

Happy Sad Weak Strong Passive Active Motivated Boredom

Fig. 2 ESM collection instrument.

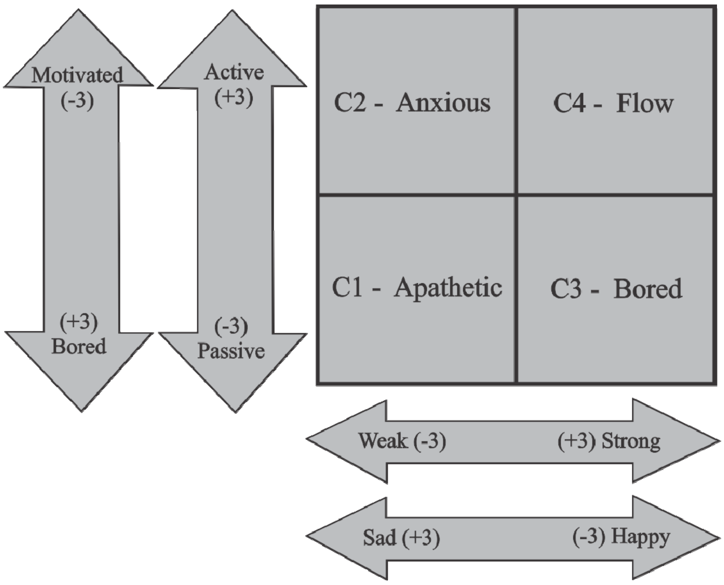


Fig. 3 Distribution chart of the 4 channels.

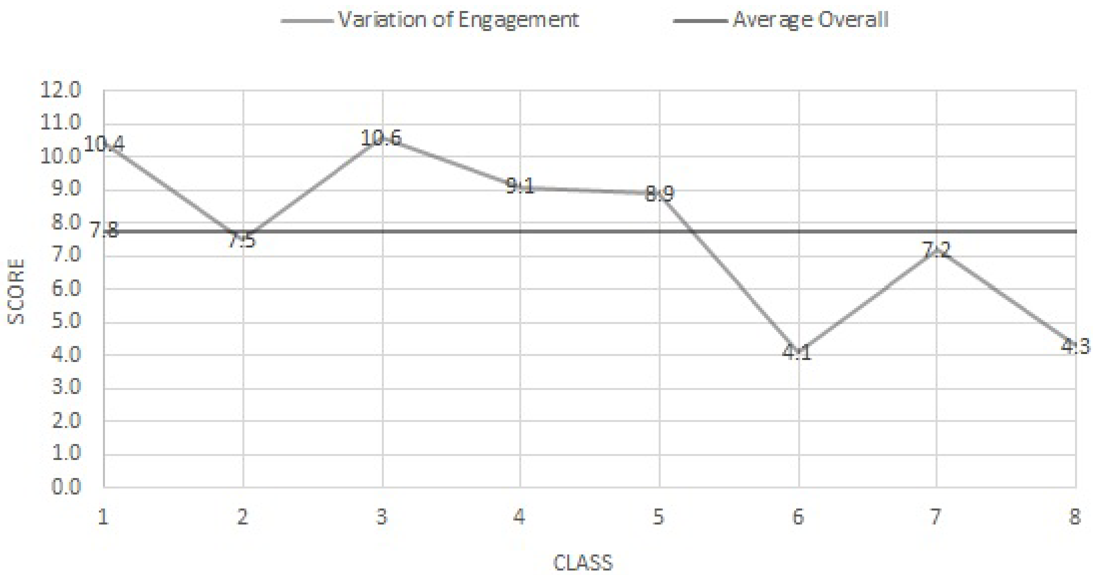


Fig. 4 Engagement performance chart of all classes.

The equation of the E (Engagement) variable is given by the following formula:

$$E = C4 - C1 \quad (1)$$

where the variable E (Engagement) is precisely the difference between the values of channels C4 (Flow) and C1 (Apathy), resulting in the trajectory of student Engagement in the activity.

Channel indices correspond to values from -12 to +12 provided with a scale of 4 values between -3 and +3 points added to a value of 12 points to all the results to facilitate the graphical visualization, therefore the numerical assignments of the scale ranged from 0 to 24 points [17-19].

After the collection of all instruments, they were analyzed and provided evidence of student Engagement in relation to the parametric design process as shown in Fig. 4. From which it presents the variable E (Engagement) of the students and was fed in the y axis with the class accompanied and in the x axis with the arithmetic averages obtained in the data collection of the ESM. Thus two curves are presented, 1st individual Engagement variable of the student; 2nd grade Engagement average.

Therefore, when analyzing the performance chart of the Class Engagement, we noticed that in three of the eight classes of Parametric Design the group had high Averages of Engagement, being Class 1 with 10.4 points, Class 3 with 10.6 points and Class 4 with 9.1 points. Thus, this study presents in the results the phenomena of these three classes in specific.

3. Results and Discussions

As results of this research is presented the measurement of Engagement of classes with greater penitential flow, that is, the moments are most conducive to learning according to flow theory. Thus, all the 8 classes included in this study were related to the parametric design theme, with theoretical subjects and practical activities, from the conceptualization of the parametric design process to the development of a parametric project using the Grasshopper plug-in for Rhinoceros 3D. Therefore, as already mentioned in the methodology, the results of this study deal only with the classes that presented the greatest potential of flow and consequently the students more engaged in the activities.

3.1 Results and Discussions of Class 1

This class had as main activity the explanation and exposition of the challenge of the discipline to be contemplated, which was carried out in groups. In this way the challenge was to elaborate a parametric children's furniture project and execute it in real size with prototyping equipment (laser cutter). As a requirement of the parametric design content the project should encompass parametrization features and be developed in the Rhinoceros/Grasshopper software, in addition to being designed for a real client, that is, a child derives from being consulted, so the students should follow the desire of this child, so at the end of the activities the furniture stayed with the child.

The second event of this class was a gamification activity in the Kahoot application, a question-and-answer game that aimed to attest to the theoretical content seen in classroom.

Next will be presented the measure the Engagement performance of students in this lesson, which averaged 10.4 on a 12-point scale (Fig. 5).

In the graph, it is possible to observe the oscillation between channels C1 (Apathy) and C4 (Flow) over time, as seen in the variable E (Engagement), where a reduction in Engagement in T3 and an apex at the T6 is shown. The drop may have been due to exposure

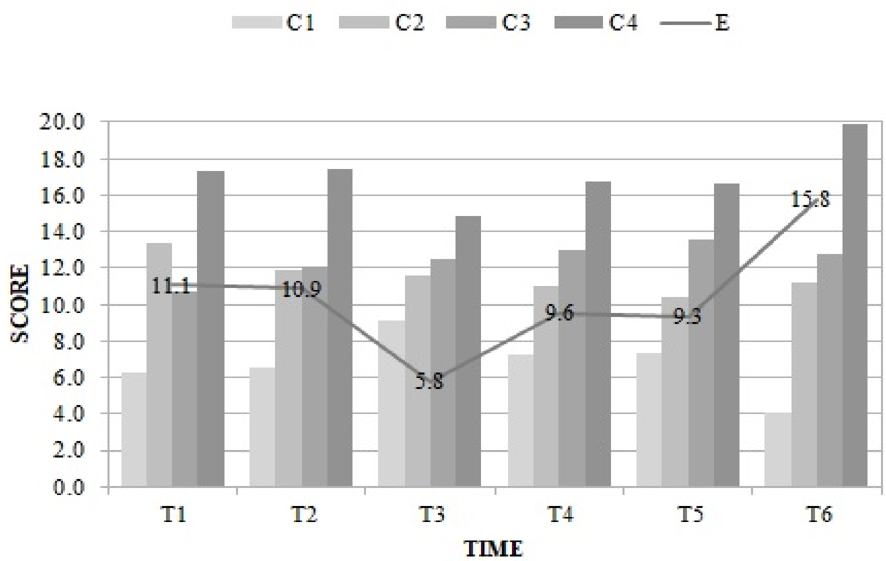


Fig. 5 Class 1: engagement performance graphic.

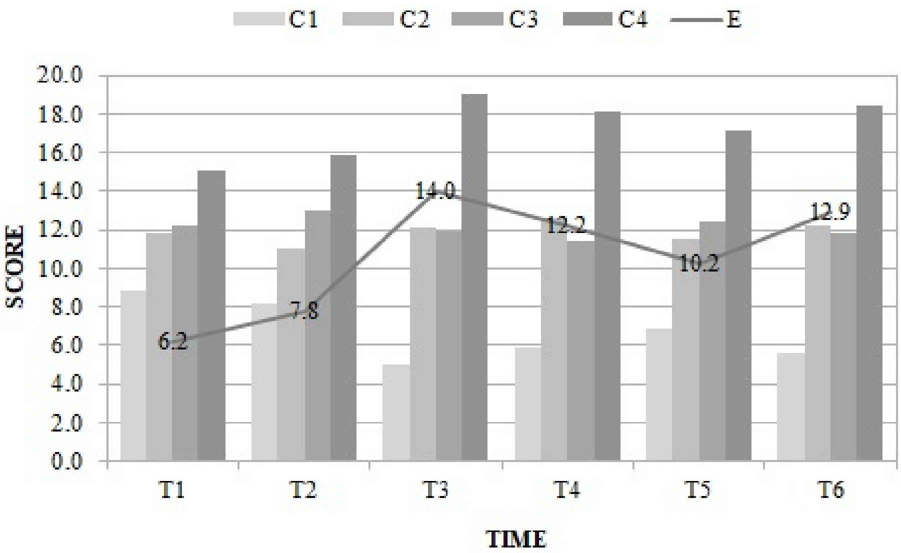


Fig. 6 Class 3: engagement performance graphic.

time to theoretical expository exposure methods (about 1:30 hours). Another relevant fact was the level of concern shown by some students regarding the sequential activities of the semester discussed at the T3, like questions: "How will the prototype be done? Manually or with the use of the equipment?", "In group?", "Will it be done in class or in extra class period?", "Will the materials be made available?", "Can different materials be used?" In T4, the variable E went up again once it was solved the doubts and concerns shown by the students.

The apex of Engagement took place in the T6, that is, at this moment the group showed greater interest and Engagement by the content of the class, which in the case was after the accomplishment of the gamification activity, a game of questions and answers. It is also possible to verify a change in the relationship between channels C2 (anxiety) and C3 (boredom) between times T1 and T3, (T2 balanced) migrating from an anxiety index to a boredom index, possibly because the group was able to understand and consolidate the content by the students' abilities, that is, the learning happened and the challenge lost value in the developed ability.

For Class 1 considerations, it was seen that the class presented an index of Engagement in this period, because when dealing with the first class of the semester it can be considered "normal" for the class to be motivated, besides the fact that the introduction of the theme until then little known by the students created a certain expectation, motivating the students in relation to the sequence of the semester. Another considerable factor was the challenge thrown to this class where basically it was the activity of gamification, which interacted the class and motivated the end of the same.

3.2 Results and Discussions of Class 3

At the beginning of this class we presented activities with an expository lecture methodology related to the theoretical content of the Parametric Architecture, with examples of architects and offices working with parametric projects around the world, as well as an introduction about what and how it works on a visual programming language algorithm on Grasshopper/Rhinoceros. Between the third and fourth moment was realized the activity of gamification with the Kahoot application regarding the content exposed in the previous moments of this class and of the texts for reading made available in the application Classroom of Google before the class. The last two moments were reserved for practical introduction activities to the Rhinoceros software and Grasshopper plug-in.

Next will be presented the measure the Engagement performance of students in this lesson, which averaged 10.6 on a 12-point scale (Fig. 6).

The graph, was noted two moments in which the group reached the highest performance of the curve E (Engagement), also seen in channel C4 (Flow) in T3 and T6, due to the activity of gamification at the time T3, and of the programming activity performed for the first time by the students in Rhinoceros and Grasshopper in time T6, also noticed that the C1 (apathy) in these moments had its lower indexes which may have been influenced by the practical and participative activities, that is, in this case the class had their best performance and pleasure in accomplishing the tasks when the challenge became operational.

As a consideration of this class it was observed that the group maintained high level of flow during the class, since the activities and methodologies presented provided this phenomenon. The class began with theory, presentation and examples of parametric projects around the world, creating a certain expectation by the class on the subject, since this subject was unknown by the students. Subsequently it was carried out activities of gamification where the class interacted with the studied content. And in the last period of the class the students had the first contact with the tool of parametrization the plug-in Grasshopper that previously was introduced.

3.3 Results and Discussions of Class 4

This class was divided in two parts. In the first one, students performed algorithmic routines in the Grasshopper, where students followed up with the demonstrations, with the purpose of introducing the tool to later assist in children's furniture projects. In the second part of the class the students had the autonomy to discuss in groups and to work freely with the project in the software Rhinoceros and plug-in Grasshopper.

The highlight of this lesson was in relation to the Engagement phenomenon, which showed an increase in Engagement in a short period of time, that is, the students left a low level of Engagement at the beginning of the class, reaching one of the highest levels of Engagement approximately two hours after the beginning of the activities, as seen in curve E (Fig. 7).

Next will be presented the measure the Engagement performance of students in this lesson, which averaged 9.1 on a 12-point scale (Fig. 7).

In the graph, a significant increase in the C4 (Flow) indexes was observed, starting at 0.8 points on the T1 and reaching 14.5 points on the T4. This may have

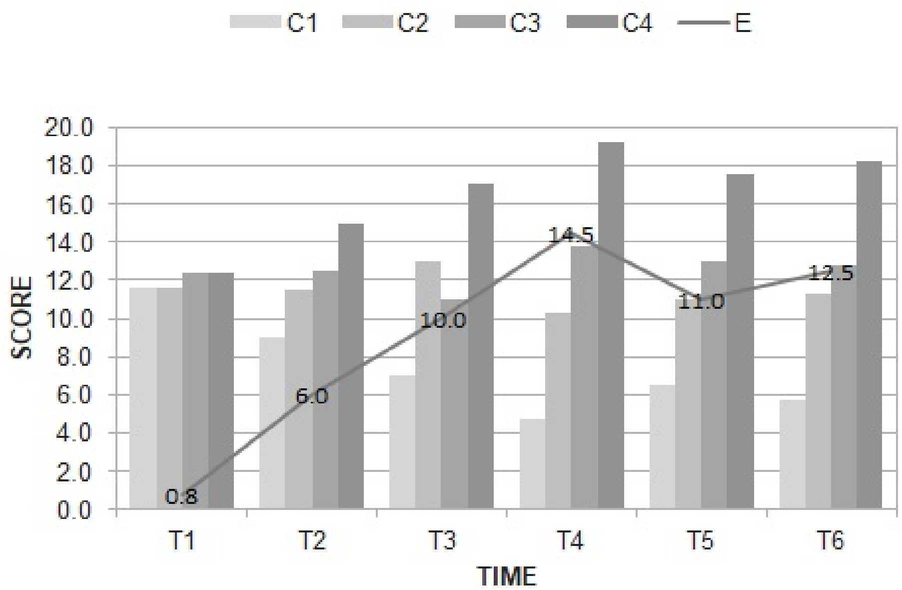


Fig. 7 Class 4: engagement performance graphic.

happened because the group was motivated by the challenge of the parametric design process, since in this class the students were working on their own with the software Rhinoceros and the plug-in Grasshopper and in general all the students were satisfied with the result of the works. This fact is also noticeable in channels C2 (anxious) and C3 (bored) where at the beginning of the lesson (T1 and T2) the group was anxious, already between the T3 and T4 moments the indexes reversed causing the students to get bored, due to overcoming the challenge established by the task.

The results of this study pointed to the flow state indexes of the class at the moments that the students were performing practical activities with PjBL methodology in the parametric modeling tool, Grasshopper plug-in, at these moments students were working on their own using computational thinking and logical reasoning with challenges and skills imposed by the activity. In this case, students reached the state of flow when they discovered the ability to solve parametric design problems by solving design challenges.

4. Conclusions

As seen in this study, teaching and learning technologies and methodologies are currently rare in higher education practice in the Brazilian context. So this study presented a research related to the insertion of new project processes in Architecture Schools that make use of technology as a form of teaching, in the case the parametric design as an innovative project process. Thus indicating how the student motivates and engages in having the contact with a new technology as well as how to build his knowledge with the help of these technological tools and active learning methodologies.

Considering these facts in the measurement of teaching of parametric design with a group of students of architecture, the intrinsic learning of content happened when the inclusion of parameterization tools such as Grasshopper for Rhinoceros allied with active teaching methodologies such as PjBL, stimulating students to develop complex jobs with parametric characteristics.

However, it is hoped that this study may contribute to the teaching/learning methods in the insertion of the parametric design process in Architecture schools, besides allowing the integration of computational thinking in the creative process of design in different contexts contributing for the career of contemporary Architect.

As a continuation of the results presented in this article, they were complemented with the use of other methodologies in the data collection as the Learning Styles Inventory (LSI) [20] and feedback form used in Boston College-USA, which indicate relationships between the learning styles of each person presenting individual perceptions of students' learning, contributing to the study of the learning state in the parametric design process using the flow theory.

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