CHAPTER 115

Mathematical modeling & bloom's taxonomy in the higher course of civil engineering

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ABSTRACT

Different techniques and didactic methodologies are used in the teaching of mathematics from the basic, secondary, and higher levels, constantly seeking to improve the results of teaching/learning and ensure the perpetuation of knowledge and the development of new knowledge and technologies. This article addresses in the format of a bibliographic review, the methodology of Mathematical Modeling (MM), compared and linked to the educational objectives of Bloom's Taxonomy, pointing out within the MM the possible reaches of the cognitive and affective domains, having as main approach the teaching of Mathematics in the higher course of Civil Engineering. The result of the work presents a proposal of an active class script, with the methodology of MM, intended for Civil Engineering academics, in which at each stage of the class are highlighted the possible achievements of the cognitive and affective objectives of Bloom's Taxonomy and, finally, the conclusion of the article highlights the importance of developing innovative methodologies in teaching, seeking the formation of ethical citizens and able to solve problems and who have autonomy, resilience, innovative critical sense, contributing to scientific knowledge and the advancement of the world.

Keywords: Mathematical modeling, bloom's taxonomy, civil engineering.

1 INTRODUCTION

According to data from INEP (2017), the number of Higher Education Institutions (HEIs) in Brazil is 2,448 units, of which 87.9% are private institutions and 12.1% are public institutions, subdivided into the municipal, state, and federal spheres. In 2017, 9,955,243 undergraduate courses were offered in the country.

Access to higher education is increasingly facilitated, due to the significant reduction of entrance exams and selection processes of HEIs, replaced by the ENEM (National High School Examination) grade and also by government programs of student financing and scholarships (XAVIER, 2015).

Still, according to INEP's higher education census, in 2017, in the Civil Engineering higher education course, 346,827 students were enrolled in all HEIs in the country, clearly indicating the high market demand for professionals in the area (INEP, 2017).

Civil Engineering is a professional branch that constantly applies mathematical, scientific, and technical knowledge to the creation of projects, control of works, structural and mechanical calculations, quantification and management of products, people, and materials, among other skills that require the full mastery of mathematics, therefore, the academic of civil engineering, at the end of his graduation should be able to exercise his professional role in the labor market, contributing safely in his community and the development of the country as a whole (PINTO E OLIVEIRA, 2010).

The constant search to improve the learning of mathematics in higher education, in which teachers aim to improve the participation, understanding, and performance of students, making them able to exercise their profession is the main motivation for the elaboration of this article that proposes the use of the methodology of Mathematical Modeling, linked to the educational objectives of the cognitive and affective domains of Bloom's Taxonomy as a didactic teaching tool.

The basic curriculum of the higher education course in Civil Engineering presents several specific disciplines that have as their mother subject mathematics; therefore, the civil engineer will constantly use mathematics in the use of his professional attributions, being able to make use of Mathematical Modeling as a tool for predictions, data analysis, simulation and discussion of problem situations in his professional context.

The sequential topics are aborted through a bibliographic review of the main definitions and clarifications about Mathematical Modeling and Bloom's Taxonomy, ensuring the reader the understanding of these two didactic philosophies, ending with a proposal/example of a class in the model of Mathematical Modeling aimed at the higher course of Civil Engineering, pointing out the possible cognitive and affective domains, which can be reached by the students, of Bloom's Taxonomy in the execution of this model class.

2 MATHEMATICAL MODELING

The Portuguese language dictionary Michaelis (2010) brings the term "Modeling" as the formulation of a model, from the verb model (to make a model). Going the meaning of the word "model" it is defined as an "object that is intended to be reproduced by imitation". Based on these definitions, it is possible to understand that Mathematical Modeling aims to create/develop a mathematical model that allows it to be reproduced or imitated.

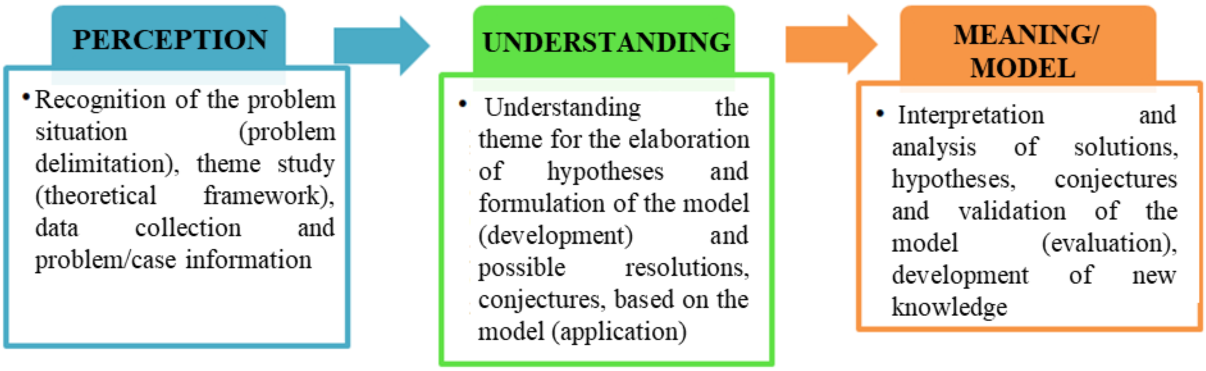
Deepening in the meaning of Mathematical Modeling, we can highlight some authors who described the characteristics of art: according to Bassanezi (2011, p. 16) Mathematical Modeling can be understood as "[...] art of transforming problems of reality into mathematical problems and solving them by interpreting their solutions in the language of the real world." In addition, Iritani (1998) defines that Mathematical Modeling aims to provide a better understanding of the world, mathematically representing what happens in nature through a conceptual model, where surveys and interpretations of data and realistic observations occur, which make it possible to anticipate future situations and understand past occurrences, allowing to direct decision making, therefore, a mathematical model "is obtained when it is possible to extract the essence of the problem-situation and transform it into systematized mathematical language" (BUENO; REIS, 2007, p. 27 apud BARROS; GAMEIROS, 2016).

Thinking in Mathematical Modeling as a teaching strategy can be quite effective, in which it presents the student with a real or semi-real problem, preferably from the everyday environment, where students will perform data collection, analyze information and present the results in a mathematical model that allows understanding, pondering and evaluating the proposed situation. (BARRELS; GAMEIROS, 2016)

Using Mathematical Modeling as a didactic tool, enables the student to have a global view of the reality in which he is inserted and favors the investigation of other areas of knowledge through mathematics. In its cognitive dimension, mathematics is related to the ability to quantify, compare, classify, measure, infer, explain, generalize, and evaluate, among other domains (XAVIER, 2015).

Biembengut (2009) organized Mathematical Modeling in a process with three main phases: perception, understanding, and signification/model.

Figure 1 – Mathematical Modeling Processes.



Source: Adapted from Biembengut (2009).

Developing mathematical modeling awakens several skills and competencies, in the first phase "Perception" are actions of less complexity, where it returns to the already existing knowledge, remembering contents, already in the phase of "Understanding" occur elaborations, more complex operations and the development of hypotheses and finally, the phase of "Signification / Model" in which the possible solutions will be presented and the evaluation of them, bearing the process presents a growing level of difficulties, challenging and awakening new knowledge and domains of knowledge (XAVIER, 2015).

In the classroom Mathematical Modeling activities involve actions such as: collecting information about the phenomenon under study (data collection), the identification and selection of case variables, the survey of conjectures, the simplification of the problem, and the creation of a mathematical model that can be evaluated.

The actions of Mathematical Modeling are preferably carried out in groups and meetings that occur the interaction between teachers/students, and students/students thus developing thinking and cooperative being (FERRUZZI; ALMEIDA, 2015).

Mathematical Modeling has several positive points in the formation of students, developing the ability of critical and autonomous researchers who can collect data, investigate, formulate and test hypotheses and validate solutions by interpreting the answers to problems, knowing how to argue, defend, communicate and work in teams (BURAK, 2019).

3 BLOOM'S TAXONOMY

According to the dictionary of the Portuguese language Michaelis (2010) the noun "Taxonomy" represents a science that performs a certain classification, organization, or systematized distribution in categories.

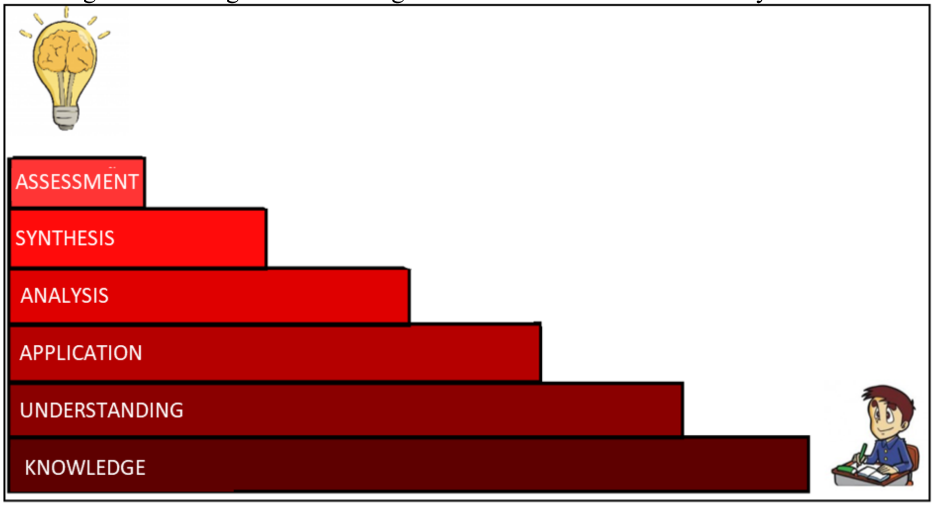
Bloom's Taxonomy is an organization of educational goals, developed in the 1950s at a convention of the American Psychological Association (APA) in Boston, involving Experts Multidisciplinary of the United States, led by the American educational psychologist Benjamin Samuel Bloom (SAINTS, 2016).

According to Bloom (1972) for the student to perform solutions to problems that require intellectual capacities it is necessary for an organization or reorganization of the problem, recognizing the situation and requiring the materials (physical and intellects) necessary to solve the problem.

During the APA convention, three organizational domains were stipulated for the intellectual development of students, namely: cognitive, affective, and psychomotor domains. The cognitive domain organizes the educational objectives on the learning of knowledge, starting from the recall and understanding of the theme under study, followed by the application, analysis, and reorganization of learning, reaching the creation, innovation, and evaluation of new knowledge (FERRUZZI; ALMEIDA, 2015).

The cognitive domains were ordered into six (knowledge; comprehension; application; analysis; synthesis and evaluation) with the first domain being the simplest to be achieved, rising to the sixth domain the most complex, thus having a hierarchy of accumulation of knowledge where the previous domain is a prerequisite to the sequential one (FERRUZZI; ALMEIDA, 2015).

Figure 2 – Categories of the cognitive domain -Bloom's taxonomy.



Source: Own author

In the affective domain are addressed feelings, emotions, behaviors, attitudes, responsibility, respect, values, acceptances or rejections of the student about the theme under study, having as domains the categories: Receptivity; Answer; Appreciation; Organization and Characterization (SAINTS, 2016).

Table 1 – Affective Domains

BLOOM TAXONOMY AFFECTIVE DOMAINS	
Domains	Actions
RECEPTIVITY	accepting, attending, engaging, studying, favoring, being interested, listening, participating, etc.
ANSWER	change, combine, complete, agree, defend, formulate, identify, integrate, modify, organize, prepare, synthesize, etc.
APPRECIATION	adapt, present, communicate, defend, demonstrate, perform, discuss, expose, explain, write, speak, opine, etc.
ORGANIZATION	Agree, help, assist, cooperate, dialogue, generalize, influence, integrate, modify, listen, etc.
CHARACTERIZATION	Welcome, argue, decide, flexible, mediate, persuade, propose, resolve, review, be ethical, verify, etc.

Source: Adapted from SANTOS (2016).

In the psychomotor domain, the educational objectives related to motor skills (physical skills), manipulation of objects, and bodily actions that require neuromuscular coordination are presented, however, Bloom et al. did not define the taxonomy (categories) for the psychomotor area (FERRUZZI; ALMEIDA, 2015).

Bloom's Taxonomy Theory is seen as a tool that enables the standardization of language on the learning objectives, facilitating the dialogue between the educational agents involved (teachers, coordinators, directors, etc.), the contents, competencies, and level of instruction desired, also serving and the basis for courses to outline their objectives and curricula, analyzing the guidelines of the local and individual context (TREVISAN; AMARAL, 2016).

In the year 1999, the mathematician Lorin Anderson and expert collaborators (psychologists, educators, specialists in curricula, tests, evaluation, etc.) proposed a new version of Bloom's Taxonomy, published in the book *A Taxonomy for Learning, teaching and Assessing: a revision of Bloom's taxonomy for educational objectives* (ANDERSON et al., 2001 apud SANTOS, 2016), where he added to the types of the cognitive domain the form and process of how to acquire them.

In Bloom's Renewed Taxonomy the six cognitive domains were treated as nouns and the procedures for reaching them as verbs. The first domain "Knowledge" has been renamed for "Remember", "Comprehension" for the verb "Understand", "Application" for "Apply", "Analysis" for "Analyze", "Synthesize" for "Create" and "Evaluation" for "Evaluate". There was also an exchange of classification of the domains "Evaluate" and "Create", where "Create" became the last domain of the group.

Table 2 – Cognitive Domains

Bloom's Taxonomy Renewed COGNITIVE DOMAINS		
Classification	Domains	Actions
First	REMEMBER	Write; List; Label; Name;Say;Set
Second	UNDERSTAND	Explain; Summarize; Paraphrase; Describe; Distinguished
Third	APPLY	Use; Compute; Solve; Demonstrate; Apply; Build
4th	PARSE	Analyze; Categorize; Rate; Compare; Contrast; Separate
5th	EVALUATE	Judge; Recommend; Criticize; Justify; Defend
6th	CREATE	Create; Plan; Elaborate hypothesis(s); Invent; Develop

Source: Adapted from SANTOS (2016)

4 CLASS PROPOSAL - MATHEMATICAL MODELING & BLOOM'S TAXONOMY

Dear reader, this topic is presented in a lesson script focused on the course Superior of Civil Engineering, where Mathematical Modeling is used as a didactic methodology, where the possible cognitive and affective domains of Bloom's Taxonomy will be scored at each stage of the classes, which aim to be achieved by the students in the case of the effectiveness of this class proposal.

CLASS THEME: Requesting Flow in Dam / Lake

SUBJECTS INVOLVED: Basic Mathematics; Analytic geometry; Dams of land; Theory of Structures; Reinforced Concrete I and II.

DURATION: 6 lessons of 50 minutes.

Nº OF STUDENTS: from 20 to 30 students.

Mathematical Modeling has a proposal to present a problem situation capable of motivating the students to seek solutions within the mathematical theory. Using modeling as a mathematics teaching strategy enables the student to answer the following question: why learn mathematics? (BIEMBENGUT 2009).

BARBOSA (1999) suggests procedures to be followed in the use of modeling:

1. Choice of a central theme to be studied by the students;
2. The capture of general and quantitative data to survey the hypotheses;
3. Elaboration of problems according to the awakening of the group of students;
4. Selection of the variables involved in the problems, formulating the hypotheses;
5. Study and sintering of the concepts and theories that will be used in solving the problem;
6. Interpretation of solutions.
7. Validation of models.

Following the script of Barbosa (1999) the present class proposes to develop a set of six classes with the theme "Flow requesting dam/lake" involving around twenty to thirty students of the Civil Engineering course enrolled in the discipline of Earth Dams that are common in all curricular grids of the referred course, present between the 5th and 8th period.

Students will be challenged to solve the case/problem of the volume of water needed for the ebb of a local dam so that it does not present problems of water overflows in the rainy season and also does not occur the drying of the waters during the drought.

This class will have the following objectives:

GENERAL OBJECTIVE: To measure the requesting flow of a dam/lake in the region, using mathematical modeling.

SPECIFIC OBJECTIVES: To understand and calculate the formulas of area and volume of the lake; Measure by practical methods the flow of rivers and streams; Analyze rainfall rates of the study region; Calculate rainfall contribution area of the lake/dam; Find the maximum requesting flow of the lake/dam; Present practical solutions for requesting flow; Evaluate the possible solutions presented.

The possible contents covered in this lesson will be the Area and volume of irregular elements; Flow and velocity of water flow; Rainfall intensity and rainfall contribution area; Construction models of dam and Sizing of ebbs.

5 LEARNING STRATEGIES

The teaching content will be approached in a practical and participatory way where Civil Engineering students will be instigated to solve mathematically the problem of the requesting flow of a certain lake/dam in the region where they are inserted, bringing the problem as close to the reality and daily life of the students.

The teacher will lead the student to the problematization in question and will make the connection between the possible ideas explored and the systematized knowledge within the perspective of mathematical modeling, following the script:

Table 3 – Lesson Script - Mathematical Modeling & Bloom's Taxonomy

METHODOLOGY MATHEMATICAL MODELING		AREAS OF SCOPE BLOOM'S TAXONOMY	
Lesson 1	Title: Field data collection. Duration: Two lessons of 50 minutes each. Development: Students will be led to a visit to the chosen lake/dam and will be divided into 3 groups, where each will have their mission to be carried out during the visit: (1) Calculate the catchment area of the lake; (2) Size the total volume of accumulated water; (3) Check the current water flow. The groups should record all the processes and methodologies adopted in the development of their mission, for later exchange of experiences with the other groups. The teacher will mediate the dubious and equivocal actions by following the entire process of data collection closely.	Cognitive Domain	In the development of "Lesson 1" it is intended that students reach the 1st and 2nd domain of Bloom's Renewed Taxonomy: REMEMBER and UNDERSTAND, that is, they must perform the following actions: remember the contents necessary for the activity; define strategies for the development of the missions, write down the information captured during the visit, list the elements visualized, describe and if necessary, illustrate all the procedures adopted for the resolution of the group's mission
		Affective Domain	In the affective field, the student will awaken domains of both RECEPTIVITY when accepting the proposed class, meeting the requests, getting involved with the development of the class, studying the contents, listening, and participating collectively. In addition to the domains of ORGANIZATION, because it is a student in a group, students should interact, cooperate, dialogue, and assist their group in the development of activities.
Lesson 2	Title: Rainfall contribution. Duration: Two lessons of 50 minutes each. Development: In the computer laboratory of the HEI, students will be grouped in pairs for an Internet search on records of rainfall intensities in the municipality of study, recording the values found. With the support of the *Google Earth Pro* program, students will check the rainfall contribution area through the "elevation profile" tool, thus finding the area of the regions with steep slopes on the shores of the lake/dam under study. During this process the teacher must present the program in question and the functionality of the basic tools in the overhead projector collectively, enabling the students to perform the activity.	Cognitive Domain	In "Lesson 2" it is expected that students work the 3rd and 4th cognitive domains: APPLY and ANALYZE, when using the computer as a didactic tool using the free program Google Earth, will compute, unveil *and* solve the proposed activity, analyzing the possible variables of the case under study, categorizing, separating and comparing the information that was obtained in the program.
		Affective Domain	The affective domain will still be worked in the student RECEPTIVITY and the ORGANIZATION and especially the domain of RESPONSE, when performing the computer tasks of alteration of information, combining and dialogue with their work duo, identifying the essential elements for the development of the activity, agree with the rules of the class and the use of the laboratory, respect other colleagues and teacher.

Lesson 3	Title: Development of calculations Duration: Two lessons of 50 minutes each. Development: To close and solve the proposed problem, the last step will take place in the classroom. First, the 3 groups of stage 1 will share with the whole class how they developed the imposed mission and what the results obtained. Soon after the pairs formed in the second stage will gather the collected data and calculate the maximum requesting flow of the dam/lake in the months of high rainfall intensity, including in this mathematical calculation all the possible variables and present probable solutions to the problem in question, performing the sizing of the ebb of the lake. Finally, each pair will present to the class what the solution model found for the problem, performing the sharing of knowledge and the validation of the models presented with the questions/contestations and collective participation.	Cognitive Domain	The development of "Lesson 3" seeks to contribute to the development of cognitive domains 5 and 6: EVALUATE and CREATE, where students will present in plenary how they reached and collected the information in "Lesson 1" defending, recommending, judging, and criticizing their presentation and that of the other groups, sharing the knowledge, hypotheses, and conjectures raised of the problem for evaluation of the whole group. In the second stage of "Lesson 3," students will create viable solutions to the study problem, elaborating hypotheses, developing calculations, and inventing resolutions, according to the understanding of each pair of students in the development of the classes
		Affective Domain	In the affective field, different skills will be worked on in "Class 3" from the domains of RECEPTIVITY, ORGANIZATION, and RESPONSE and especially the domains of APPRECIATION and CHARACTERIZATION, because the student when presenting in groups the data collected in "Class 1" will communicate, explain, defend, demonstrate, discuss, expose and opine on their presentation and the other groups. During the development of the calculations and creation of the possible solutions the students will take positions of decision, mediation, and persuasion, will propose solutions trying to solve the problem, verifying and test the hypotheses and solutions as to coherence and veracity.

Source: Own author

6 MATERIALS USED

The material used for "Lesson 1" is up to the groups to decide thatThe equipment or sources of information will be used for the collection of data from the dam/lake, according to the search methodology chosen by the group, however, the following materials may be suggested by the professor:

- Trena, rope, rod, small fishing boat, stopwatch, PET bottle 2 liters, permanent marker, booklet.

For "Lesson 2" held in the computer laboratory of the IES, the following equipment/materials are required:

- 15 computers with internet access, *Google Earth Pro* software installed on each computer*, projector, whiteboard, whiteboard marker, calculator, and notebook for the projector.*

7 EVALUATION SYSTEMATICS

The systematic evaluation is at the discretion of the regent teacher, respecting the rules and didactic procedures of the HEI involved, however, it is suggested that the evaluation be continuous, diagnostic, and comparative, observing the active participation of students throughout the classes and analyzing the presentation in plenary of the knowledge acquired.

8 FINAL CONSIDERATIONS

Mathematical Modeling linked to the cognitive and affective domains of Bloom's Taxonomy can contribute significantly to the teaching practice within higher education, developing in the student human and professional skills that go beyond the content taught, forming ethical citizens and able to deal with various problems situations of their daily lives, possessing autonomy, resilience and innovative critical sense in the face of the adversities of personal and professional life.

This article by pointing out the domains of Bloom's Taxonomy that can be achieved in the development of a class with the methodology of Mathematical Modeling for Civil Engineering classes, emphasizes the versatility of this didactic tool and its great contribution to the field of knowledge, making it multidisciplinary and of great relevance for teaching.

The approximation theory with practice, proposed by Mathematical Modeling, arouses in the student greater interest when addressing cases/problems of everyday life, occurring a contextualization of the contents where the subjects involved will be able to investigate, debate, build concepts and hypotheses that leverage the domains of multidisciplinary knowledge and with greater interaction between students and teacher.

Developing motivating and differentiated classes that reach the participation and understanding of the student, taking him out of his "state of comfort" is the great mission of the educator to achieve scientific knowledge and contribute to the advancement of the world.

It is expected that from the class proposal presented in this work, teachers will be motivated to perform and analyze the practical effectiveness of Mathematical Modeling in achieving the educational objectives of Bloom's Taxonomy for the development of future works.

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