**International Electronic Journal of Mathematics Education**
2022, 17(4), em0711
e-ISSN: 1306-3030
https://www.iejme.com

MODESTUM

**Research Article** **OPEN ACCESS**

# Aspects of attitudes towards mathematics in modeling activities: Usefulness, interest, and social roles of mathematics

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**Citation:** Lopes, A. P. C. (2022). Aspects of attitudes towards mathematics in modeling activities: Usefulness, interest, and social roles of mathematics. *International Electronic Journal of Mathematics Education, 17*(4), em0711. https://doi.org/10.29333/iejme/12394

**ARTICLE INFO**

Received: 03 Jun. 2022

Accepted: 17 Aug. 2022

**ABSTRACT**

This study addresses three aspects of the attitude towards mathematics: usefulness, interest, and recognition of the social roles of mathematics. Mathematical modeling activities were developed and conducted with engineering students. We analyzed how the attitude towards mathematics is manifested in this context and what contribution can be to a better understanding of the aspects of this attitude. We note that interest is manifested in a personal and objective way and that there is a recognition of the usefulness of basic mathematics in everyday life and in other contexts to the detriment of higher education mathematics. In addition, modeling proved to be a good opportunity to recognize the social roles of mathematics, something that did not occur individually. We conclude that modeling is pointed out as a means for a manifestation of a good attitude towards mathematics.

**Keywords:** attitudes towards mathematics, interest, usefulness, roles of mathematics in society, modeling

## INTRODUCTION

The attitude towards mathematics can be the way in which a person likes mathematics or not and can also involve the level of mathematics that such a person deems necessary to learn and understand (Hannula, 2002; Ma & Kishor, 1997). Some factors such as gender can influence this attitude (Opstad, 2021; Salifu et al., 2021). Some research has shown that students' attitudes have a considerable relationship with various aspects and the teaching method adopted by the teacher can be an essential factor in changing attitude (Parhizgar & Liljedahl, 2019). In environments where the educator plays a supporting role, students begin to have more favorable attitudes towards mathematics (Akey, 2006; Parhizgar & Liljedahl, 2019). One methodology that can contribute to a positive attitude towards mathematics is modeling.

According to Lingefjard and Holmquist (2005), students are used to a methodology that does not demonstrate much of the applications of mathematics in real life. When introduced to mathematical modeling, some claim not to be familiar with this methodology, but all recognize that modeling can be used to study everyday situations and that it could be incorporated into the curriculum. Going in this direction, Blum (2002) raised the following question: "What is the potential of modeling to provide an environment to support students and teachers in developing appropriate attitudes towards mathematics?"

For Di Martino and Zan (2011), there are three themes (or dimensions) in the relationship with mathematics: emotion, vision of mathematics and perceived competence. Several aspects can be related to these themes. For example, utility can be considered as an aspect of the view of mathematics and interest as an aspect of emotion. In addition, a fourth theme can relate to the attitude towards mathematics, the social theme.

Utility (or the perception of utility value) is one of the aspects of student motivation (Gilbert et al., 2014). According to Hannula (2006), "motivation has not been a popular topic of study lately". The perception of usefulness can increase confidence, leading to learning and better performance (Hulleman et al., 2017). According to Heymann (2003), mathematical knowledge in general achieves greater usefulness when using modeling, even university students can see mathematics as relevant to themselves through modeling (Hernandez-Martinez & Vos, 2018).

Interest is an affective attribute, a positive emotion that also relates to motivation, also considerably concerns mathematics education (Ko et al., 2021). According to Hannula (2002), interest is a basic emotion in which other complex emotions derive. Interest can be described as a "specific relationship between a person and an object in its 'space of life'" (Krapp, 2000, p. 11), such as a person's relationship with mathematics (Schukajlow et al., 2012). Student-centered methodologies and dealing with modeling problems can benefit interest in mathematics (Schukajlow et al., 2012).

The social theme of the relationship with mathematics can involve several aspects. Real-world issues can be controversial and involve debates, moral and ethical issues that can be emphasized in teaching and learning procedures. Researchers such as Barbosa (2006) and Stillman et al. (2013a) point out that addressing such issues in a classroom through mathematical modeling demands the application of the sociocritical perspective, an education project for democracy (Artigue & Blomhoej, 2013). According to Ikeda (2018), "recognition of the roles of mathematics in society has an important goal in the teaching and learning of mathematical modeling", in addition, "there has been little progress in teaching and learning focused on the multiple roles of mathematics in society in the modeling literature."

The recognition of the roles of mathematics in society, interest and usefulness are some of the aspects of the relationship with mathematics. According to Schukajlow et al. (2012) few works "addressed selected attitudes towards mathematics". In addition, Schukajlow et al. (2018) added that there is a "significant lack of papers that investigated emotions, beliefs or motivation". These three aspects are the focus of our study.

We conducted a survey with engineering students in the discipline differential equations in order to analyze these aspects of the relationship with mathematics. For this, we conduct mathematical modeling activities of real problems, because modeling is considered a good option for engineering teaching and can assist in the recognition of usefulness (Hernandez-Martinez & Vos, 2018; Heymann, 2003), arouse interest (Schukajlow et al., 2012) and in the development of critical thinking and in the recognition of the social role of mathematics (Barbosa, 2006; Gutiérrez & Gallegos, 2019; Ikeda, 2018; Stillman et al., 2013a).

## ATTITUDE TOWARDS MATHEMATICS

Like Di Martino and Zan (2011), we have separated the relationship with mathematics into three themes:

1. Emotional disposition in relation to mathematics.
2. Vision of mathematics.
3. Perceived competence to succeed or not in mathematics.

We add a fourth theme of the relationship with mathematics:

4. Social and critical aspect.

Next, we will delve into some of the aspects concerning the themes of the relationship with mathematics. We will address the role of interest in emotional disposition and the role of utility in the view of mathematics, in addition to addressing the social and critical issue.

### Role of Mathematical Modeling

Akinsola and Olowojaiye (2008) showed that the teaching method has a significant influence on the attitude towards mathematics, as well as the relevance of mathematics disciplines. In addition, a study conducted by Parhizgar and Liljedahl (2019) showed that a student-centered pedagogy contributes positively to a student attitude, to the detriment of traditional teacher-centered methodology. A possible pedagogy in this direction is mathematical modeling. Modeling activities can help both in learning mathematics and understanding mathematics in reality (Lingefjärd & Holmquist, 2005).

According to Heilio (2011, p. 487), the mathematical modeling of real-world problems is an "ideal way to build interest and enthusiasm" and has a positive impact on student performance (Schukajlow et al., 2012). For Schukajlow et al. (2012) the interest "really profit from the divergent solution structure of modeling problems".

For Bracke and Geiger (2011), the use of modeling can increase interest in challenging problems and produce a change of attitude in mathematics in general. According to Parhizgar and Liljedahl (2019), modeling problems connected to reality can motivate engagement among students and improve the vision in relation to mathematics. Similar results were presented by Eric (2011) and Schukajlow et al. (2012). Although modeling can bring positive results in the attitude towards mathematics, it is important to balance the difficulty of the modeling problem and an adaptation to mathematical development (Parhizgar & Liljedahl, 2019).

### Use

According to Parhizgar and Liljedahl (2019), "motivation plays an important role in learning". Just like interest, usefulness is related to motivation.

The interest and value of utility are predictors of performance, engagement, and effort (Kim et al., 2015). If there is no interest in a mathematical activity, the perception of the value of utility becomes a motivational factor that allows students to get involved (Ryan & Deci, 2000) and generates an improvement in performance (Kim et al., 2015; Simons et al., 2004).

Although there are studies on the positive relationship between interest and usefulness, there are contradictory studies (Kim et al., 2015). A study with university students (Cole et al., 2008) pointed out that the perception of usefulness considerably indicated effort and performance, while interest did not. But, therefore, the value of perceived utility can generate interest (Hidi & Renninger, 2006). Another research with university students (Durik & Harackiewicz, 2007) found that the value of utility generated motivation only in students with a high personal interest in mathematics. In addition, the perceived competence in mathematics can exert an important factor, that is, just knowing the value of utility may not be enough for students to get involved in an activity. For example, students with low perceived competence may not get involved in an activity, even recognizing the usefulness, because it assumes that it will have a non-expressive result (Ryan & Deci, 2000). That is, students may not be interested in an activity, although it may have a high utility value.

The perception of usefulness is also related to the way students feel motivated. Students engage in activities if they feel motivated, extrinsically, or intrinsically (Ryan & Deci, 2000). According to Ryan and Deci (2000), intrinsic motivation is generated by the interest or pleasure of an activity in itself, and extrinsic motivation is related to the value of the usefulness of the activity. The perception of the value of utility (or instrumentality) involves how a task is identified as relevant and useful for both present and future objectives (Kim et al., 2015). The value of utility can be intrinsic if the value is important to the person. On the other hand, the value of utility is considered extrinsic when someone engages in an activity to obtain a certain result, such as improving performance in mathematics to enter a university.

Although mathematics is present in various everyday contexts, a person does not need to connect his goals to mathematics. This is largely due to the advancement of technology, which leads people to make use only of basic mathematics (Heymann, 2003; Hulleman et al., 2017). This situation is the paradox of relevance, which is a "discrepancy between objective social relevance and its subjective visibility" (Niss, 1994), because students cannot make a connection between classroom mathematics with their reality. On the other hand, modeling assists in the applications of non-basic content in reality, since in order to translate the real problem into a mathematical model, improved mathematical knowledge is required. Thus, the use of modeling can increase the value of the usefulness of mathematics beyond standard applications (Niss et al., 2007).

Another important aspect of the relationship with mathematics and that is also associated with motivation is interest.

### Interest

Interest is a modern concept that Immanuel Kant used in the field of aesthetics. For Kant (2007), interest is the pleasure we associate with the representation of the existence of an object and this pleasure is linked to desire in a determining or relative way. In turn, for Hegel, interest is the "moment of subjective individuality and its activity, i.e., it is the presence of the subject in action" (Abbagnano, 1971). However, it was Hebert who systematically used the concept of interest in education (Abbagnano, 1971). According to him, interest is the result of forces of attraction and repulsion in various representations (Abbagnano & Visalberghi, 1992) and comes before the action, that is, the means between being a spectator of facts and intervening in them, a participation not completely engaged. Similarly, interest is different from desire, because it comes before, even without the existence of an object. Finally, the one who most insisted on the importance of interest was John Dewey (1910, p. 89), defining it as the "monitoring of the identification, through action, of the self with some idea or some object, which leads to the maintenance of self-expression". Dewey (1978) mentions that interest brings the idea of feeling fascinated and that it motivates the commitment to do a certain task, in a completely absorbed way. For him, some aspects of interest are related to these words: dynamic, objective, and personal. We present these concepts below and add other related ones.

Interest is dynamic because it leads the person to some action, not to a passive attitude. That is, if there is interest, there is some movement, in some direction, in search of something. In this way, interest is deeply linked to a goal, otherwise it will lead to emptiness, a uselessness. The personal aspect of interest is related to the appreciation or appreciation of an object, which has subjective perspectives, linked to emotion, and objective perspectives, related to ideas and/or objects. Thus, interest is an internal activity with the purpose of reaching an object with its value judgment.

The direct (or immediate) interest is one in which the activity performed is the end in itself, not the means to a different end. On the other hand, indirect (or mediate) interest occurs when something that does not arouse a direct interest relates to something of interest to you. This may be the case with mathematics, because it may not be interesting until you make use of its various applications. With this, it is worth the idea of making something interesting. The boundary between indirect and direct interests is tenuous, what was a means becomes an end. Interests can interconnect within a system (Schunk et al., 2008).

The transferred interest occurs when initially you do not have pleasure in something or do not like it, but it becomes interesting, since this "something" is a means to achieve something that caught our attention, that is, the interest in the end absorbs and transfers interest in the means. So, we can say that the interest has been transferred from one object to another. For example, in a modeling, a student may agree to perform the activity so as not to displease the teacher, but when performing the modeling he discovers that he likes the subject and the interest becomes the activity, no longer in pleasing the teacher. This same situation can occur when the theme is chosen by the teacher and not by the student.

We emphasize that the evolution of the movement, engaged in an action, is accompanied by emotions, leads to expansion and a feeling of fulfillment, constituting happiness. On the other hand, if the activity is monotonous, with no news, it becomes, finally, uninteresting.

Schutz (1979) deepens Dewey's (1978) ideas and highlights levels of relevance within a specific interest of a problem and that this interest has a personal and a social facet. Personal interest is socially conditioned, but it is personally that what is problematic or not is determined at a time. For example, a student may be interested in solving a derivation, as this will allow him to solve an optimization problem, but this student may become fascinated by the derivation process and his interest in mathematics becomes mathematics itself.

On the other hand, in the social sphere, the interest in Bourdieu (1994) is related to the idea of *illusio*, that the game (from the Latin *ludus*) is worth playing and the target pursued. For the author, interest is an illusion, a belief that a specific social issue is important to be conquered. The *illusio* is the fascinated relationship with the game, the interest in pursuing it, the product of an ontological complicity engendered between mental structures and the structures objectified in a social space. Interest can be socially constituted when there is a relationship with a social space within which certain things are important. For example, in our modeling context, a student may be interested in modeling by witnessing the hard work of colleagues and begins to try to reach the target, that is, to produce the model. Some researchers have applied Bourdieu's (1994) ideas in the field of mathematics education (Jorgensen et al., 2014) including in some aspects of the attitude towards mathematics (Quaye & Pomeroy, 2022).

### Social and Critical Aspect

Some of the competencies of the 21st century involve critical thinking and "skills for living in the world: citizenship, life and career and personal and social responsibility" (Maass et al., 2019). The skills of this century can be grouped into three dimensions: information, communication, ethics, and social impact. In each of these dimensions there is at least one important (social) role: decision-making, critical thinking and "social responsibility and awareness of social impact" (Maass et al., 2019). Critical thinking involves searching for and interpreting information.

For Maass et al. (2019), mathematics plays an important role with regard to "responsible citizenship" which also involves an international political agenda linked to education. This agenda highlights the relevance of acquiring "acquire social, civic and intercultural competencies by promoting democratic values and fundamental rights, social inclusion and active citizenship, and by enhancing critical thinking and media literacy". Students should be able to act in society responsibly, understanding global challenges (climate, financial, food and epidemic issues). Such questions are presented by the media, through graphics and symbols, which require mathematical competence. Despite the recognized importance of the formation of responsible citizens "issues such as ethics, equity and social justice, it has not been prominent in promotion of STEM education" (Maass et al., 2019).

Like Gibbs and Park (2022), we recognize "that stimulating reflective discussion is an ongoing lifelong process for students as critical citizenship requires informed engagement and action outside of the classroom" (Frankenstein, 1983; Niss, 1994; Skovsmose, 1994). In a traditional math class, students are receivers of knowledge. On the other hand, activities such as mathematical modeling are opportunities to stimulate critical reflection and lead to a type of empowerment (Gibbs & Park, 2022).

According to Di Martino (2019), mathematical modeling should also cover a "critical approach towards the real world" that relates to an "active citizenship" because it has universal relevance and legitimizes the teaching of mathematics for all, which goes beyond future choices. In the modeling environment, getting involved in self-reflections means questioning not only one's own beliefs and principles, but also those concerning the phenomenon investigated, the modeling process and the consequences of the implications of the model.

Modeling from a sociocritical perspective, according to Barbosa (2006), is established through reflective discussions during the modeling process. This type of discussion is established from the beginning of the modeling process, reflecting on the criteria and nature of the phenomenon under study to the outcome of the social implications of the model (Skovsmose, 1994). A reflective discussion should transcend the classroom, being a constant process in critical citizenship (Frankenstein, 1983; Niss, 1994; Skovsmose, 1994).

An aspect of this social and critical theme is the perception of the roles of mathematics in society (Ikeda, 2018). Students may have a perception from some points of view (Ikeda, 2018): social perspective, clarity of roles and context of these roles in a general or specific way. In addition, a perception of the nature of the phenomena studied, of the decision-making processes involved, requires a maturity in critical reflection (Barbosa, 2006; Gibbs & Park, 2022; Skovsmose, 1994). According to Ikeda (2018), "little progress has been made concerning the teaching and learning focused on the multiple purposes of mathematical modeling in the modeling literature", in addition, "teaching and learning to deepen student perceptions of the roles of mathematics in society is an important issue to be addressed".

### Research Question

How is the attitude towards mathematics characterized during the modeling process, in view of the aspects of usefulness, interest and perception of social roles? In addition, what is the influence of modeling on this attitude? And what contribution can there be to the themes of attitude to mathematics?

## METHODOLOGY

The modeling activities were carried out in two classes of students from nine different types of engineering at a Brazilian federal university. The types of engineering involved outside: environmental engineering, computer engineering, control and automation engineering, electrical engineering, materials engineering, mechanical engineering, mobility engineering, production engineering, and health and safety engineering. The 117 students were enrolled in the discipline differential equations. In the first class, the 52 students formed 9 groups and, in the second, the 65 students formed 11 groups. In each group there were four to six students, chosen by them.

The modeling activities were carried out in the first half of 2020, in the months of June and July. Due to the COVID-19 pandemic, the university has adopted exceptional remote teaching. Thus, the classes were held in synchronous meetings with the help of Google Meet. The modeling was carried out in 10 meetings, and each meeting lasted 110 minutes.

Each group made two models, choosing one in the 1st modeling block, which involved 1st order ordinary differential equations (ODE's) and another involving higher order ODEs, in the 2nd block. After the end of each block, there was a presentation of each group of its results and discussions. Finally, after performing the modeling activities, each student answered a final evaluation questionnaire in order to ascertain the attitude towards mathematics, individually.

The modeling followed the steps outlined by Biembengut (2016). It presents three steps/steps for realization in the classroom:

(a) perception and apprehension.

(b) understanding and explanation, and

(c) signification and expression.

In the first stage (a), there is an initial (intuitive) understanding of the phenomenon, highlighting the variables, and formulating the equation to be solved. Next, in the second stage (b), the equation is solved, and graphs are produced. In the last stage (c), the solutions must be interpreted “in terms of the real problem” (Burghes & Borrie, 1981, p. 14). It is at this stage that the validation and interpretation of the results takes place and where most critical discussions take place.

The themes of the modeling were mainly inspired by the book by Burghes and Borrie (1981) and were chosen in order to motivate students and because they are possibly linked to the lives of all students in some way. Caron and Belair (2007) and Galbraith et al. (2010) suggest social contexts as modeling topics. According to Yoshimura (2015), a modeling that addresses a social context can be motivating for students, even if the theme is chosen by the teacher. The themes were:

1. 1st block:

   1A. Alcohol absorption in the body and the risk of accidents.

   1B. Diet-how to optimize weight loss?

2. 2nd block:

   2A. Consumer buying behavior.

   2B. Spread of an epidemic.

The synchronous meetings with the students were recorded and the database was Moodle. This database included a discussion forum, the development of the modeling made by the groups and the final questionnaire. In addition, the researcher who was also a teacher of the course, adopted a field diary. Then, the questionnaire was developed in order to capture students’ perceptions of mathematics, including questions such as: How do you perceive people’s relationship with mathematics in everyday life? Do you consider basic or higher mathematics useful in everyday life? In what aspects did modeling contribute to reframe your mathematical knowledge?

We hoped that the promotion of activities related to the real world could not only benefit the learning process, but also improve the motivation of students, bringing interest, a positive view of the usefulness of mathematics in everyday life in addition to the perception of the social and critical aspects involved.

A set of coding categories was developed with a view to the theoretical perspective. The coding categories were divided into two types: categories for the perception of the social perspective of mathematics (category S), one category for the perception of the usefulness of mathematics in everyday life (category U) and another for interest in mathematics (category I). The data were categorized by the researcher and teacher of the course, who acted in order to be a non-participating observer. Then, the data checked with those of a second researcher, in which minimal differences were observed. The data we present from the groups were obtained mainly from the final part of the modeling process (registered in Moodle) and from the presentations made, while the individual data were collected from the questionnaires mainly but complemented by the observations of the weekly meetings. Students answered the questionnaire (also in Moodle) so that they could put long written answers if they wanted to. We analyzed the 102 answers obtained from the questionnaires, even if some were succinct, because they were relevant to our analysis. In this way, it was possible to perform content analysis (Bardin, 1977), which we complement with some basic quantitative data. Validity was established through interviews with students. Reliability was obtained by comparing the results of the researcher observers

The following is a delineation of the first modeling. The acronym T1G1 stands for group 1 of class 1 and so on and the real names of the students have been replaced by fictitious ones.

### Modeling 1-A: Absorption of Alcohol in the Body and the Risk of Accidents

In the first stage of modeling (perception and apprehension), there was an initial understanding of the phenomenon, highlighting the variables and formulating the ODE to be solved. Therefore, the students established discussions, which were around the following problem: how to develop a mathematical model that addresses the risk of a person getting involved in a traffic accident after drinking an alcoholic beverage?

The groups recognized that not only the amount of a particular drink can affect, but also the type of drink, because there is a difference in alcohol content. Soon after, with the help of the aforementioned reference (Burghes & Borrie, 1981), the groups equated the phenomenon. Then, they solved the differential equation (**Figure 1**) that related the risk of accident R to the concentration of alcohol in the blood b. After that, the groups sketched graphics (**Figure 2**)–performing stage 2 of Biembengut (2016) (understanding and explanation). After obtaining the solution function of the ODE of the modeled phenomenon, the groups outlined the graphs of this function (**Figure 2**).

In the third stage, the groups validated and interpreted the model and made connections with reality. Most of them started this stage based on the graph produced. For example, the T2G4 group said that “from the general solution we obtain in the differential equation, we see that there is a dependence between the variables. This model is best explained by the increase in the exponential curve generated in the graph”. He then added: “the risk of a person suffering an accident after drinking is greater with the increase in alcohol consumption, as there is an increase in the rate of alcohol in the blood”. We observed that this group was able to perform an interpretation of the phenomenon in mathematical terms, but there was no connection with social issues.

On the other hand, the T2G9 group recognized that “the risk of someone getting involved in a car accident after drinking alcohol is high, and it is expressly necessary to make the population aware so that they do not do so”. In probing this comment, we noticed that the group went beyond mathematical discussions, that is, it recognized that it is of paramount importance to carry out a social action (raise the population), due to the consequences and implications of the model.

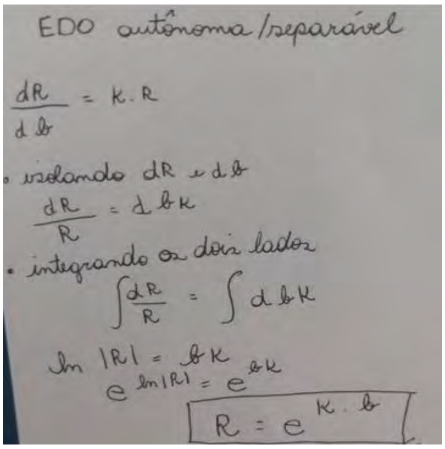


**Figure 1.** An ODE resolution of the phenomenon by a group (T2G8)

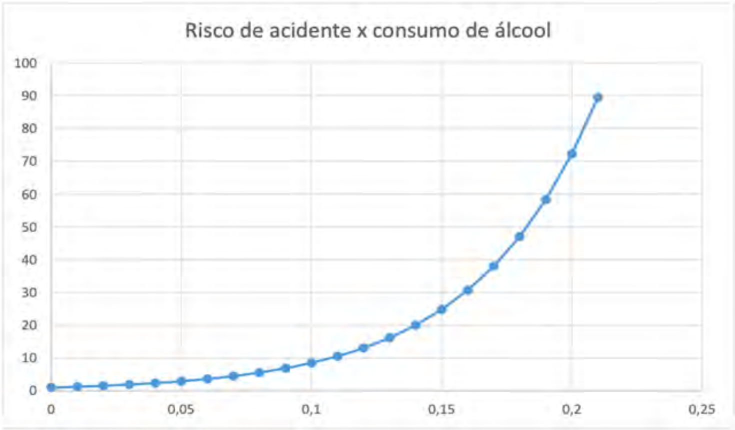


**Figure 2.** Sketch of the graph (risk of accident *R* vs the concentration of alcohol in the blood *b*) of the solution function *R(b)* obtained by a group (T2G1)

## RESULTS–DATA AND ANALYSIS

We start with the categories of the social perspective as shown in **Table 1**. We are inspired by Ikeda (2018), who presented similar categories for the social perspective of mathematics in modeling. We established the categories that distinguished students' compressions about the roles of mathematics in society. To this end, we assessed the ability of students to perceive the roles of mathematics in their personal life or in a social context and the influence of mathematics on decision-making processes.

The responses of students who adopted personal, but not social, perspectives were attributed to category S1. Expressions such as "I use mathematics in my financial control" or "I use mathematics only to organize my day and shop", present the use of mathematics in personal life, but not in society, so these and other similar expressions we attribute to the category S1. Answers that indicated a social perspective, but in a general context, lacking articulation and without specific examples, were attributed to the category S2. By way of example, the expression "mathematics is present in everything in a person's daily life" was attributed to category S2. In addition, the answers that show a specific context, but not general, recognizing that mathematics is practical in some contexts were attributed to category S3. An expression, such as "mathematics is present in the sizing of sewage treatment plants" was attributed to category S3. Answers with specific examples and that mention a general context, showing that mathematics is useful for understanding a phenomenon or making decisions have been attributed to category S4. For example, an expression such as "mathematics is present in our daily lives, even when you go to the bakery, you need it" was assigned to category S4. Finally, the answers that indicated the recognition of the influence of mathematics on society were attributed to category S5. For example, the expressions "mathematical models are basing the decision of governments" or "the government can take protective measures to control the spread of the virus, based on the projection of the model" were assigned to category S5. Students assigned to categories S3, S4 or S5 were considered able to understand the social roles of mathematics (Ikeda, 2018).

We noticed that several students did not present a social perspective when answering the questionnaire. These students cited only the use of mathematics in contexts in which they are familiar to them. For example, for Aline mathematics can be used "most of the time, from the time it will take me to get to a certain place, as well as the amount of water and calories I have already ingested on the day, the value of purchases" Ennio, on the other hand, employs mathematics "in everyday life in supermarkets, virtual games and where basic mathematics fits". We noticed that the perspective used in these cases was personal, because there is no social context of a more general nature mentioned. Thus, comments like these were attributed to the first category of the social perspective, S1.

**Table 1.** Social perspective

| Category type | Criterion | Expression example |
|---|---|---|
| S1 | It presents a personal perspective only, but not a social one. | I use mathematics in my financial control. |
| S2 | It presents a social perspective, but of a general character. There are no concrete examples. | Mathematics is applicable in many everyday activities. |
| S3 | It presents a social perspective, but only in a specific context and not a general one. | High school mathematics matches the practice of mathematics in informal accounting and commerce. |
| S4 | It presents a general and specific social perspective. | Mathematics is present in people's daily lives, like calculating a diet and shopping. |
| S5 | It presents a critical reflection. | Through mathematical modeling we understand severity of Lei Seca that imposes punishments for minimum blood alcohol limits. |

On the other hand, category S2 we add those who presented a general social perspective, even if they have presented some personal examples. For example, for Álvaro "mathematical would be able to transform an entire society for the better" and for Vanessa, "mathematical is linked to the development of civilization and basic knowledge is necessary for personal development". In addition, Natan mentioned that "mathematics enters many more areas of everyday life than I imagined, which surprised me and can model human behaviors". As he did not present specific examples of applications of mathematics in society but presented the general aspect "modeling human behavior", we also attribute this comment to the category S2. These students of categories S1 and S2 recognize the usefulness of mathematics whether in personal life or in society. But as they lack specificities and, especially, critical reflection, we consider, like Ikeda (2018), that students in this category do not recognize the social and critical role of mathematics. We noticed that most of the students were in one of these categories. But as we will discuss a little later, the situation of the groups was different.

We continue in the case of the individual perspectives demonstrated; we have those who presented a specific social context. According to Carla, "we see mathematics when a newspaper presents estimates of how many people can be affected by a disease or virus". A comment like this was posted in category S3. On the other hand, Carlos Alves said that "mathematical is perceived in everyday life in various ways. Some examples are in the financial area, such as counting money and pricing products". Comments like this we consider belonging to category S4. Finally, those who presented some critical reflections were attributed to the last category S5. We noticed that there were few students who made this type of reflection. For example, Gustavo said that "through mathematical modeling we understand the severity of Lei Seca[1] that imposes punishments for minimum blood alcohol limits". Thus, he recognized that mathematics and, in particular, mathematical modeling are behind decision-making processes. Although a smaller number of students are considered as connoisseurs of the social role of mathematics, several groups presented a different perspective.

Some groups highlighted only a few specific aspects of the modeling developed. The T2G7 group said that "to create an improved mathematical model for the adequacy of a diet, the desired objective must be considered. For this, some variables such as weight, height, age, diseases, etc." Groups like this were included in category S3. On the other hand, several groups went further and expressed some evidence of critical reflection.

We noticed that most of the groups fit into category S5. The T2G9 group found that "the risk of someone getting involved in a car accident after drinking is high, and it is expressly necessary to make the population aware not to drive after drinking". On the other hand, the T1G1 group, when analyzing the strategies adopted by companies, recognized that "we need to know more about how a brand exerts social, economic and political influence on a region, state or country". Several groups modeled the spread of an epidemic (modeling 2-B), still in the uncertainties of the beginning of the pandemic and when the existence of a vaccine was in an unforeseen and distant scenario. Thus, at the end of the modeling process, such groups established critical discussions. For example, the T1G4 group, when talking about the importance of the model today, discerned that "this is important because it helps in the faster development of a vaccine to combat the disease". The T1G7 group, in turn, added

> "The model gives us the perspective and estimate of how many people will be infected, the lethality of the disease and the number of deaths. This allows you to have a plan to prevent real life from reaching mathematical projection. Therefore, the measures to be taken will be according to the severity and the way it is transmitted, whether it is social isolation, use of masks, among other precautions until a vaccine is developed."

Groups that made comments like this we consider as connoisseurs of the social role of mathematics, which was the majority. But, on the other hand, when making an individual analysis, few students presented this understanding. In order to obtain a better understanding of the qualitative data and compare what was done by the groups and individually, we made use of some basic quantitative data.

**Table 2** shows below the different social perspectives, according to categories S1 to S5, adopted by groups and students individually. When it comes to the groups, we had a very expressive result in category S5: 75% of the groups presented a critical reflection, reflections that were mostly for actions of the government (40%), or companies (20%) than in other contexts (40%).

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[1] Law 11,705, popularly known as Lei Seca, was passed in 2008 in Brazil with the purpose of reducing traffic accidents caused by drivers who are under the influence of alcohol. It is available at http://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2008/Lei/L11705.htm (Accessed on September 28, 2021).

**Table 2.** Quantitative social perspective

| Category type | Criterion | Quantity in groups | Individual quantity |
|---|---|---|---|
| S1 | Presents a personal perspective only, but not a social one. | 0 | 32 (31.3%) |
| S2 | Presents a social perspective, but of a general character. There are no concrete examples. | 0 | 31 (30.4%) |
| S3 | Presents a social perspective, but only in a specific context and not a general one. | 7 (35%) | 3 (3%) |
| S4 | Presents a general and specific social perspective. | 0 | 26 (25.5%) |
| S5 | It presents a critical reflection. | 15 (75%) | 10 (9.8%) |

**Table 3.** Use of mathematics in everyday life

| Category type | Criterion | Expression example |
|---|---|---|
| U1 | Recognizes the usefulness of mathematics but does not specify which level of education. | Mathematics is present in every moment of my life. |
| U2 | Recognizes the usefulness of basic math. | I use more basic math, especially in financial control. |
| U3 | Recognizes the usefulness of higher mathematics. | I used integration principles to calculate the amount of flooring. |

**Table 4.** Relationship between the level of mathematics and its context of use

| Level\context | Daily life | Job | University | Do not recognize usefulness |
|---|---|---|---|---|
| Basic | 78 (76%) | - | 8 (8%) | 16 (16%) |
| Higher education | 14 (14%) | 12 (12%) | 29 (28%) | 47 (46%) |

However, on an individual basis, this reflection fell dramatically, because less of the students' meta-age were in categories S3 to S5. On the other hand, most students presented a personal perspective or a general social perspective (categories S1 and S2).

In the analysis of the questionnaire, we noticed that many students mentioned financial mathematics, either in a general or specific context (categories S1 and S2), saying something like "financial mathematics is useful" or "I use financial mathematics when shopping in a supermarket".

Another aspect of the attitude towards mathematics is its usefulness. In order to better understand what type of mathematics the student considers useful in everyday life; we consider category U–see **Table 3**. In category U1, we included students who recognized the usefulness of mathematics in everyday life but did not identify which level. These students used generic expressions such as "mathematics is useful in everyday life" or "only basic mathematics is useful in everyday life". We have included in category U2 expressions that indicated the usefulness only of basic mathematics. An expression such as "we use basic mathematics on a daily basis (sum, subtraction, division and multiplication)" was attributed to category U2. Those who perceived the use of higher mathematics in everyday situations were assigned to category U3. This is the case of the expressions "I used integrals to calculate the volume of cement to be used in home retirement" and "I will use higher education mathematics only in my future work as an engineer".

We noticed that many students recognized the usefulness of basic mathematics. For example, Varlene uses mathematics "in simple situations such as when standing up and defining the right measures to make coffee". Another student, Raisa, acknowledged that "we use mathematics when we are going to pay something and we have to receive some change (subtraction), when we need to account for our expenses during the month (sum)". She added that we also use mathematics "when we want to share a food with our brother and this division should be perfectly in half (division), or finally when we are for example making a recipe and we need to double the ingredients of our recipe (multiplication)".

Adriano said that "the branches of mathematics that I use the most are geometry and logical reasoning". Several students, like him, recognized the usefulness of mathematics in the development of logical reasoning. Another aspect widely commented by the students was the use of financial mathematics. For example, Adam said: "I use it in my financial control and in some leisure time, such as games in which they require logic and prior knowledge to analyze statistical data". According to Geraldo, "in any situation that requires logical reasoning, technically, we make use of mathematics".

On the other hand, we note that a smaller portion of students recognized the usefulness of mathematics learned in higher education. For Carine, the use of this mathematics helps to "develop logical reasoning and reason in other disciplines". She added: "higher education mathematics is clearly focused on the professional environment and on the training of the student in logical thoughts used interdisciplinarity".

In view of the utility categories, we consider that students assigned to categories U2 and U3 appreciate the usefulness of mathematics, because those in category U1 presented vague statements. We emphasize that some groups were included in both category U2 and category U3 because they presented the usefulness of mathematics from both the basic and higher levels. We obtained 17% of students in category U1, 71% in category U2 and 50% in category U3. Therefore, considering that students assigned to categories U2 and U3 appreciate the usefulness of mathematics, we note that most of them recognize the usefulness of mathematics. In order to delve a little deeper into this point and identify the context of the usefulness of mathematics, we elaborated **Table 4** (in which 100% is all students). That is, for students who have identified which level of mathematics they consider useful (basic or higher), we specify the context (work, college, daily life).

We noticed that most students recognize the usefulness of basic mathematics, especially in everyday life, whether for shopping, household chores, etc. On the other hand, a smaller number of students found the use of higher mathematics in some context. Of these, some said that higher mathematics is useful only at the university, either in some other discipline, or in some

**Table 5.** Interest in mathematics

| Category type | Criterion | Expression example | Percentage amount |
|---|---|---|---|
| I1 | Recognizes factors that may impair interest. | Mathematics taught in schools is not the same as that used in everyday life. | 37 (36.3%) |
| I2 | Shows dynamic interest. | I was encouraged to research and watch videos that would help understanding. | 7 (6.9%) |
| I3 | Shows personal interest. | I use math when cooking to calculate the amount of an ingredient, oven time, etc. | 62 (60.8%) |
| I4 | Shows objective interest. | A practical application is essential to understand the content. | 46 (45.1%) |
| I5 | Shows direct interest. | Modeling helped me identify constants, variables, make relationships with graphs, and manipulate equations. | 12 (11.7%) |
| I6 | Has indirect interest. | The activities opened my mind to the countless possibilities of ODE's, something I had not imagined. | 30 (29.4%) |
| I7 | Shows a transferred interest. | Using modeling will help me in Statistics. | 15 (14.7%) |

project that is involved (scientific initiation for example) or in the elaboration of the course completion monograph; others said that university mathematics will be useful in the context of future professional work and not many have stated that higher mathematics is useful in everyday life. We noticed that some students have said that the use of higher mathematics in other contexts (academic or professional) will be facilitated through computer programs that will make the necessary "accounts". Few students (16%) did not mention the usefulness of basic mathematics, but several students (46%) did not recognize the usefulness of mathematics in higher education.

In addition, a third point of view concerns the student's interest in mathematics. We will indicate below the types of interest presented by the students (**Table 5**).

The criterion for category I1 was the recognition of factors that harm interest, such as precarious prior education (especially in public schools) and the lack of applications of the content learned. One student even said that basic mathematics is not useful, but higher mathematics - a reflection of the precariousness of the teaching of some Brazilian public schools. Some students simply said, "school mathematics is not useful". Several students have recognized that mathematics is difficult, distant from people and that it is complex to relate it to everyday life. According to Ana Luiza, "the mathematics taught in schools is very contentious, but little practical, which generates disinterest in students". Flaviana added: "the mathematics taught from high school to college is a little distant from people's lives, because they are more specific subjects that are often not used beyond the classroom".

In category I2, we include expressions that denote the dynamic interest, that is, an interest that led to some action. For example, a student said, "I was encouraged to research". This indicates an action, so we include it in category I2. We emphasize that few students were included in this category.

In category I3, we consider personal interest as an appreciation linked to emotions and some of the personal contexts such as: use of mathematics in some family enterprise. Albert mentioned: "I work with the financial part of a restaurant, every day, from 6 p.m. to midnight. In this sense, basic mathematics applies completely to my daily life". Gabriel has already been involved with a renovation: "since we are going through a moment of renovation at home, I am always having to calculate the quantities of material to buy. Recently I even used some principles of an integral to calculate the amount of floor I would have to buy for a circular area". Other cases of personal interest that went beyond the renovation of the house was the construction of some object. For example, Fernando acknowledged: "when I'm building skateboard ramps, geometric mathematics is very important". Another personal interest was the use of mathematics to help relatives and colleagues. Diana said: "I try to use my knowledge to find ways to teach other people in simple ways".

Objective interest in category I4 was often presented by the satisfaction in working with a mathematical application. We noticed that students crave this, possibly this is because they are engineering students. They said something like "I liked the modeling, because I was able to see applications of ODE's". In addition, many simply said that they liked the modeling activities, because they were able to see that mathematics is useful in some context. This kind of interest we might not find in a class of students of "pure mathematics", due to the fact that many of these students show interest in mathematics for their own mathematics or for applications in the discipline itself. By way of example, Aline said: "with modeling I was able to see practical examples for differential equations, and it made it easier for me to understand". For Sandra, "the most significant part was to open my mind to see how modeling is used in everyday life".

In relation to category I5, direct interest, we perceive the influence of the context. In the months of June and July 2020, when the activities were developed with the students, the new coronavirus pandemic was beginning. At that time, the future was still uncertain, there was no specific date for a vaccine, and many were adapting to academic activities via home office. Thus, many who have shown an interest in modeling 2-B (propagation of an epidemic) well possibly because of the lived context. One student said that "modeling was the best thing that happened in remote learning", an expression that we interpret as an indication that the modeling activity was the end in itself, therefore, belonging to category I5. Not many students have been assigned to this category.

At first, category I6, indirect interest, was not clear to us, due to the concise expressions of some students, which led us to have doubts whether some of these expressions could not be in category I7 (transferred interest). However, in a careful and careful analysis, considering all the data produced, we have separated these categories well. Some students showed indirect interest (category I6) when they said they were not interested either in modeling or discipline, but the activity performed aroused interest (Dewey, 1978). A portion of the students, as well as Katia, said they "did not imagine that the content of differential equations would be applicable in everyday life" and were surprised by the applications seen, which aroused interest in mathematics.

Alessandro acknowledged that "the applications in our daily lives for differential equations are numerous and I did not imagine such a thing". Aline, in turn, mentioned: "modeling opened my mind about the numerous possibilities of using ODE, something I would not have imagined if I had not researched and studied about".

We identified the interest transferred (category I7) when students transferred the interest in mathematics or modeling to other disciplines and some other contexts. This means that, because of the activities carried out, students were interested, for example, in content from other courses (such as those related to physics or statistics). For example, Carlos said that this methodology "would serve mainly in physics and chemistry". Carlos mentioned another course: "modeling can be used in Statistics, since we would have a vision of how to estimate statistical data of a given phenomenon".

In **Table 5**, we quantify the interest in mathematics according to the categories presented. Students included in categories I2 to I7 were considered interested in mathematics, in other words, we realized that most students showed some interest in mathematics.

We observed that the sum of the percentages in **Table 5** is greater than 100% (where 100% is all students). This is due to the fact that some student expressions are placed in more than one category. For example, Lucca's following comment we attribute to categories 1 and 3: "In the teaching of mathematics in schools, applications are not emphasized (...) I use financial mathematics to control my expenses". We noticed that this student, in addition to recognizing factors that harm interest, presents a personal perspective of interest.

## DISCUSSION

We can see in **Table 4** that many said that basic mathematics is useful in everyday life (category U2). For these students, mathematics is useful for personal finance, development of logical reasoning, making measures when preparing a culinary dish or for making estimates, such as in video games. The discrepancy between the large number of students who appreciate the usefulness of basic mathematics, but one small for higher mathematics is in accordance with Heymann (2003). We agree with this author that modeling can increase the perception of the usefulness of higher mathematics, given that many students were surprised to see applications of ODEs in everyday life, which is also in harmony with Niss et al. (2007). Half of the students directly said they appreciated modeling with differential equations. For example, for Sara "what caught my attention the most was to see the use of modeling at the moment we are now living with this epidemic". In one of the final meetings, Alexandre said: "I liked the work done and found interesting how to treat everyday problems with mathematics". In this same meeting, Albert mentioned "with this methodology we fix more and learn better". Aurora also expressed herself: "I thought the modeling activities (even if it was a lot of work) were good for us to be able to see the application of what we learned. I had not had any subjects like this, and I found it very interesting". Tatiana also appreciated the methodology adopted:

> "I really enjoyed taking the course and with the modeling work I was able to better understand the concepts. I had already done the subject before and there was kind of a blockage with differential equations, but I was glad I saw that it's nothing so dreadful. I do not have a blockage anymore. I'm even more excited to do numerical calculation!"

In view of the students' comments, we agree with the inferences of Czocher et al. (2021) regarding the role of modeling: it is an active and student-centered pedagogy that helps to realize the relevance of mathematics both in everyday life and in the future career; there is an increase in interest in learning mathematical content and a consequent increase in motivation Although a few students did not feel comfortable with modeling, because they said they were not familiar with this methodology, most appreciated the activities developed. In addition, some said they were in favor of the use of modeling in other courses. In other words, they expressed a transferred interest. This finding is in line with other studies (Lingefjard & Holmquist, 2005).

Regarding the interest, we noticed that many students expressed an objective and personal interest. Objective interest was directly linked to the satisfaction of seeing practical applications of content while personal interest was manifested in the use of mathematics in personal finances, personal projects, and family enterprises. Not a few students have expressed an indirect interest. That is, they did not have an interest in the mathematical content addressed but began to appreciate it during and after the activities. The interest after the activities also manifested itself in the interest by transferring a desire to use this methodology in other contexts, in other courses. The expression of interest was accompanied by a recognition by several students of factors that have damaged interest in mathematics throughout their lives, especially precarious teaching, and lack of applications.

In addition, as shown in **Table 2**, a reasonable amount adopted category S1, presenting a personal social perspective of mathematics (Hulleman et al., 2017) and together with category S2, we obtain the majority of the students. As we are considering students in categories S3 to S5 as those who perceive the social and critical role of mathematics, we note that few have recognized this role at the individual level. The individual evaluation of the social perspectives of mathematics, made through a questionnaire after the completion of the modeling activities, showed a discrepant result, 9.8% presented a critical reflection (category S5) and 25.5% adopted a general and specific social perspective (category S4) and 3% presented a specific context (category S3). That is, we observed that 38.3% of the students understood the social and critical role of mathematics, while all groups understood this role. This may indicate the need to encourage critical reflections on the social roles of mathematics and the importance of group work for such discussions.

We emphasize that some competencies are important in the social theme, such as critical thinking. In a literature review, Rogovchenko et al. (2020) noted some practical and utilitarian points of modeling. According to these researchers, these points are more evident in engineering and science, because they have favorable reasons to do mathematical modeling. For these, there is not only an interest in mathematics itself, but also in the implementation of models in society.

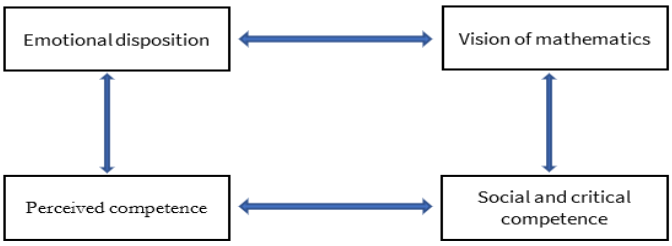


**Figure 3.** Four-dimensional model for attitude towards mathematics

Two of the eight recommended skills for inclusion in the mathematical configuration of PISA 2021 are: critical thinking and reflection (Schukajlow et al., 2012). In addition, as pointed out by Di Martino (2019), mathematical modeling should also cover a "critical approach towards the real world". This is in harmony with other researchers such as Barbosa (2006), Gibbs and Park (2022), and Schukajlow et al. (2012). In this way, we extend the 3-dimensional model to the attitude towards the mathematics of Di Martino (2019) and Di Martino and Zan (2011) to a 4-dimensional model in which it covers the social and critical theme, as illustrated in **Figure 3**.

McLeod (1989) divided affection into three subdomains: emotions, attitudes, and beliefs. DeBellis and Goldin (2006) extended to a fourth subdomain called values/moral/ethics, thus creating a tetrahedral model. Similarly, for a broad understanding of the attitude towards mathematics, we see it important to include the social and critical theme, which covers some aspects such as the roles of mathematics in society (Ikeda, 2018), and critical aspects that involve values, ethics and the reasons for decisions both to equate a model and to act with it in mind (Barbosa, 2006; Frankenstein, 1983; Gibbs & Park, 2022; Niss, 1994; Skovsmose, 1994; Stephan et al., 2021).

There is evidence that students are motivated during modeling activities, even if this is specific to the task (Bonotto, 2010; Kaiser et al., 2011; Maass, 2010; Schukajlow et al., 2012; Stillman et al., 2013b). According to Gibbs and Park (2022), the personalization of mathematics is important to encourage reflective discussions. That is, modeling activities that cover the personal lives of students can stimulate the auxiliary interest in the vision of the social value of mathematics (Barbosa, 2006). A personalization of the modeling will result in an engagement of students in a social issue that is familiar to them not only personally, but also socially and culturally. In this way, there will be expressive reflections in addition to significant connections of mathematics to their lives. As we noted, the context of modeling seems to indicate an improvement in the students' reflective discussions, something found, for example, by Gibbs and Park (2022).

Considering what has been said, we note that most show some kind of interest, especially the personal and objective, many have a view of the usefulness of mathematics, especially the basics and have a perception of some social aspects of mathematics, an emphasis on groups. Thus, we can conclude that mathematical modeling presents good opportunities for a favorable attitude towards mathematics. The positive impact of the attitude towards mathematics is in harmony with the works of Bracke and Geiger (2011) and Parhizgar and Liljedahl (2019). In addition, we observed that, for many, mathematics is seen as a technique and a tool for an end, such as use in some daily activities and in the professional future. We could identify this type of interest as instrumental interest. In this sense, instrumental interest is presented as an objective perspective of personal interest. In view of this, we consider that personal interest can go a little further, because it is disconnected from personality, and can be more objective and pragmatic than personal. A student may have a personal interest in mathematics but express this interest in an instrumental way or it may be that another student has only one instrumental interest and not a personal one. It is like using a computer, because we can use it due to the imposed needs (of work, for example) and thus have an instrumental interest, and this does not mean that we have an understanding or appreciate a programming language or that we appreciate technological innovations, but that we use the computer for a purpose, such as writing a text. That is, relevance does not necessarily turn into a value of interest and personal utility, which must be linked to individual objectives (Hulleman et al., 2017). However, we do not think it is convenient to make this differentiation by concise expressions, without a clearly expressed objective or affective personal perspective. That is, to be more precise, it is important to investigate the boundaries between interest (instrumental and personal) and between the usefulness of mathematics.

Another challenging aspect is the questions in the questionnaire. For example, the question 'Do you find basic or higher mathematics useful in everyday life?' It contains the words "you" and "useful", which can lead students to express themselves considering only personal experiences in relation to mathematics and disregarding the use of it in society. Thus, it is important to use appropriate questions, so that students express themselves about their beliefs, the usefulness of mathematics in society and the perceptions of the roles of mathematics socially, highlighting in addition to how their interest is given. This leads us to think about the limits of categories S2 and S4, which should be discussed and analyzed with caution. On the one hand, a person can recognize the role of mathematics in society but express himself only in personal terms. We recognize, like Gibbs and Park (2022), that the discourses produced by students throughout modeling on a microsocial level are more subtle and require detailed discourse analysis. With this in mind, interviewing some students will be important in later work.

Another limitation found is related to the context. The models were produced remotely and during the beginning of the pandemic. In this way, students' perceptions and perspectives may have been affected - for example, 12 of the 20 groups were interested in modeling 2-B (propagation of an epidemic). Thus, limitations of our study suggest a direction for future work. We recognize, additionally, that the choices of the groups, a self-selection, may have had some influence on the answers in the final questionnaire. The individual perspective may have been modified, for example, through a more incisive colleague. Possibly, the individual responses also tend to be more consistent with the group's perspective. Future research may elucidate that point.

## CONCLUSION

From the analysis, we can say that most students had an interest in mathematics and this interest was expressed in several ways, just as most students recognize the usefulness of mathematics in everyday life, especially basic mathematics. In addition, they recognize the roles of mathematics in society, but this varied individually and in group work, since individual critical reflection was small and that of the groups was greater.

Unlike some studies (Liebendörfer & Schukajlow, 2020), we note that the recognition of mathematical applications, that is, the usefulness of the content, directly affected the interest of students. This motivated them to be more engaged in their studies (Hulleman et al., 2017). However, this recognition manifested itself mostly from basic mathematics. We emphasize that almost half of the students did not recognize the usefulness of higher education mathematics (but only basic mathematics), and, on the other hand, most appreciated the modeling activities because of the practical view of abstract content. Thus, we infer that the most usual use of this methodology may increase the level of recognition of the usefulness of higher education mathematics–something that future research may see. As few students have noticed the usefulness of higher mathematics in everyday life, therefore, it is important to ask ourselves: Why is not higher education mathematics perceived as having applications in the daily lives of students? Would this be due to the fact that in traditional higher education classes in mathematics disciplines they focus only on the theoretical part, leaving aside the applications? What is the influence of technologies in this regard?

True interest (Dewey, 1978) means that the person has met himself in the course of an action, for this reason there is an identification of the person with the object, and he begins to act in a happy way in this course. In this sense, we can say that many of the students acted happily. Modeling has the potential to increase students' interest in mathematics, as already highlighted in previous research (Czocher, 2019), which includes engineering. (Czocher et al., 2021) and this pedagogical alternative can be incorporated into the curriculum, even on small scales. This is the case with advanced mathematics content, such as differential equations, in which it can be challenging to maintain a positive attitude towards mathematics (Czocher, 2017; Rasmussen & Kwon, 2007). Practical applications of abstract mathematical content can arouse interest in the content covered and this interest can extend to other courses. Future work can investigate how interest is socially constructed, that is, the development of *ilussio* (Bourdieu, 1994), which could explain the difference between looking at mathematics at the individual and group level (Jorgensen et al., 2014; Quaye & Pomeroy, 2022). In addition, the most frequent use of modeling in various contexts and content can not only maintain interest, but also improve it. Therefore, we recommend the use of this methodology for this purpose.

Although we identify that most students recognize the roles of mathematics in society, it becomes clear that it is difficult to maintain reflection and critical discussion in this regard on a personal level. Students lack incentives to develop critical reflection and recognize the social roles of mathematics. On the other hand, group work seems to be a driving factor in this direction, since critical discussions were significantly greater in the groups than individually. We recommend that discussions about the social roles of mathematics be made more consistently, as well as an incentive to critical reflections on the implications of the use of mathematics in society. These discussions and reflections are not customary in disciplines known to be technical as differential equations. That said, modeling activities can help by working with real-world problems and by involving group activities, which seems to facilitate and stimulate discussions and reflections.

We realize that modeling can reach the arguments of Niss and Blum, explained more recently in Niss and Blum (2020). That is, students can develop skills (Lu & Kaiser, 2021); they can develop critical skills; they experience modeling in real contexts (Niss & Blum, 2020); they adapt the image of mathematics and its role in the world and assist in the understanding of mathematical concepts, motivating study in other disciplines. In addition, we note that modeling can contribute to the perception of the usefulness of mathematics in everyday life (Kim et al., 2015; Niss et al., 2007), a positive attitude towards mathematics (Bracke & Geiger, 2011; Parhizgar & Liljedahl, 2019), which means awakening or increasing interest, in addition to the vision of the roles of this discipline in society (Ikeda, 2018).

We conclude by inferring that modeling activities present themselves as a good opportunity for the manifestation of a positive attitude towards mathematics. In addition, the social and critical aspect is a dimension that can be included in the attitude towards mathematics. Thus, along with emotional disposition, perceived competence and vision of mathematics, a four-dimensional model of attitude to mathematics is plausible. According to Blum (2002), when studying attitudes in modeling, we should also reflect on the implications for changing practice in the classroom and modeling. The most frequent use of modeling with differential equations, with a contextualized theme taken from reality and that is attractive can help maintain interest in the content addressed, improve the perception of the use of mathematics in other contexts, contribute to the perception of the usefulness of mathematics at all levels, especially at the higher level, in addition to contributing to the perception of the social and critical aspects of the roles of mathematics, that is, collaborate to the development of critical reflection, not only through a group activity, but also at the individual level.

Future work may elucidate other points. We consider attitudes towards mathematics during modeling activities. A later work can investigate the variations of this attitude, that is, how mathematical modeling influences the change of attitude towards mathematics through a before and after comparison, as done by Parhizgar and Liljedahl (2019) in the context of elementary school and through the tool introduced by Ikeda (2018).

**Funding:** No funding source is reported for this study.

**Ethical statement:** The study received approval from the Brazilian Ethics and Research Committee (*Comitê de Ética e Pesquisa* – CEP) on November 24, 2019 with code 24670619.7.0000.5150.

**Declaration of interest:** No conflict of interest is declared by the author.

**Data sharing statement:** Data supporting the findings and conclusions are available upon request from the author.

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