# Chapter 18
# Mathematical Modelling as a Learning Environment to Transform a Street Activity into a Sport Practice

**Daniel Clark Orey, Milton Rosa, and Rogério Braga Soares**

**Abstract** This chapter shares research in regard to a specific sports practice and discusses its potential for educational contexts. A sports activity has significant potential that can transform students' lives. Thus, a specific street activity in Brazil named *carrinhos de rolimã* (*roller carts*) can be linked to mathematical ideas through the modelling process developed in an alternative learning environment. This approach was an opportunity to deepen students' understanding and broaden their critical reflections on this well-known street activity in their own context and community. From this practice, researchers propose the configuration of sporting modalities in a modelling learning environment that may lead to a competition in which students fairly compete among themselves.

**Keywords** Critical and reflective dimensions · Educational sports engineering · Learning environment · Mathematical modelling · Mixed methods study · Sports practices · Street activity

## 18.1 Introduction

One of the main objectives of this study was to apply mathematical modelling as a learning environment in order to contribute to the restructuring of teaching practices. In this context, one of the greatest challenges for teachers is to link theory with practice in their teaching by transforming a well-known street activity in Brazil called *carrinhos de rolimã* (*roller carts*) into a sport practice.

D. C. Orey (✉) · M. Rosa · R. B. Soares
Departamento de Educação Matemática – DEEMA, Universidade Federal de Ouro Preto – UFOP, Ouro Preto, Minas Gerais, Brazil



G. A. Stillman et al. (eds.), *Mathematical Modelling Education and Sense-making*, International Perspectives on the Teaching and Learning of Mathematical Modelling, https://doi.org/10.1007/978-3-030-37673-4_18

For the purpose of this study, traditional roller carts are constituted of a wooden body with three or four ball bearing wheels with a movable axis for steering and control. The construction of these carts is simple and diversified, and they vary somewhat in size and shape as well as in regard to the use of different materials and terrain they are used on. The roller carts are mostly made from recycled materials such as demolition wood and discarded ball bearings. A roller cart is known as a toy used by young people in many countries made by using simple tools such as a hammer and a saw. Figure 18.1 shows one of the most common types of Brazilian roller carts built with a wooden frame and discarded steel bearings from automotive repair shops.

It is important that teachers are supported to develop activities that arise from the students' own interests. In this regard, modelling and sport can be used to develop students' interest in diverse and sophisticated academic content that enables them to grow in their ability to use mathematics. Sport and its distinct forms of competition may challenge students and motivate them to increase their willingness to learn mathematics. Hence, Rosa and Orey (2007) state that a modelling approach is useful in coming to understand and comprehend problems, situations, and phenomena that emerge in the everyday life of students. Therefore, the following research question was proposed: *What are the contributions that a mathematical learning environment involving the construction of a roller cart and subsequent sports competition in which students fairly compete among themselves can provide?* According to this query, it is important that students are given opportunities to recognize how mathematics can play a role in organizing fair, competitive, and efficient sports events (Malkevitch 2017). In this context, mathematical modelling is understood as a learning environment in which students, through the development of mathematical activities, are invited to both inquire and investigate situations originating in other non-academic/textbook areas of reality (Barbosa 2006).

In this study, modelling is considered part of a learning environment that helps students to develop and exercise data-based opinions, creativity, and criticality through the analysis, generation, and production of mathematical knowledge in relation to the construction of roller carts. Through modelling, this context provides

**Fig. 18.1** Brazilian roller cart. (Source: Authors' personal file)

both real and concrete opportunities for students to discuss the role of mathematics as well the nature of mathematical models (Rosa and Orey 2015).

This context enabled the authors to state that modelling provides a learning environment that aims to facilitate the investigation of phenomena (street activities and sports) through the elaboration of contextualized pedagogical activities (construction of roller carts) that help students to use mathematical knowledge to solve problems proposed in the classrooms. Thus, Noubary (2010) states that the widespread interest in sports, in our culture, provides a great opportunity to catch student attention in mathematics classes.

In this chapter, we outline a teaching methodology with focus on the critical and reflective dimensions of mathematical modelling that is based on the understanding of students' daily activities. This teaching strategy enables students to learn how to analyse and take action in regard to problems they face in their own contexts.

## 18.2 Mathematical Modelling and Sports: Roller Carts

Most people think that mathematics is only applied to the sciences and engineering, yet it is also used in other disciplines. Although it is not always perceived this way by the population, mathematics plays an important role in sports. For example, coaches use mathematical formulas to improve athletes' performance (Malkevitch 2017) and discuss statistics related to the achievement of players and teams.

In this context, Lewis (2003) focused on the *Oakland Athletics* baseball team's analytical evidence-based and statistical approach to assembling a competitive team. For example, in the United States, baseball statistics possess almost a cult status for many followers of this sport. The same is true in countries in which soccer is one of their main sports. Noubary (2010) also stated that sports provide an inexhaustible source of fascinating and challenging problems for many disciplines. For example, the use of mathematics includes the determination of the best batting order for a team to maximize the number of runs a player can score or the scoring systems for some of the complex and subjective aspects of sports events.

In addition, mathematical influences can be seen in the formalization of instruments used by athletes and para-athletes. This includes balls, rackets, wheelchairs, prostheses, court sizes, fields and demarcations, and pools and their dimensions. In this regard, we have proposed a practical way to develop mathematical modelling in classrooms through the elaboration of models in relation to the development of sports practices related to roller carts. According to Noubary (2010), this approach shows that through sports, many students can be exposed to the basics of mathematical modelling and statistical reasoning using a context that interests them.

Considering that the roller carts are powered from the initial impulse given by the pilot, and by gravity, this study helped the students to connect mathematics and science to their daily life. Here, many learners were motivated to perform calculations that examined the development of, and acceleration achieved by, the carts. Calculations in the design and construction of the roller carts included those related to the mass, circumference and diameter of the wheels, the number of wheels, geometric shapes of the fixed and movable parts of its structure, the measurements related to the axles and the wheels, the length of the main axles, as well as the overall symmetry of the cart and its aerodynamics. These calculations may guarantee a certain standardization of this equipment and, consequently, a more judicious and fair competition for competitors.

In this regard, Orey (2011) argues that mathematical modelling establishes a bridge between sports practice and mathematics, which brings important contributions to pedagogical action developed in classrooms by providing an autonomous, cooperative, meaningful learning environment that leads learners to the development of creativity and criticality. This approach is related to the transformation of academic mathematics into a living subject that is connected to real situations in time and space that allows students to critically analyse and reflect upon mathematical phenomena that occur in their own communities (D'Ambrosio 1999). The origin of many mathematical ideas is the result of a process that sought to solve problems or explain and understand phenomena observed in reality. These ideas can be translated from elaborations of mathematical models whose acquisition, application, and evaluation are linked to the process of mathematical modelling.

## 18.3 Methodological Procedures

The data collection and analysis as well the interpretation of the results of this study were performed by applying a *Mixed Methods Study* design *QUAL+quan*. In this design, a quantitative approach was embedded within a predominantly qualitative study. The plus sign refers to the qualitative and quantitative data that were collected and analysed simultaneously (Creswell and Plano Clark 2007).

This investigation was conducted with 34 students in a public night school context. The participants' ages ranged from 18- to 33-years old, and all were in the second year of high school in the *Youth and Adult Education Program* in the Belo Horizonte metropolitan region, the state capital of Minas Gerais, Brazil. The third author was the teacher of these students.

In this study, *educational sports engineering* (Brothwell 2016) was applied in association with the modelling tasks related to designing, building, and testing (validating) the roller carts by regulating and standardizing their dimensions, which were used to analyse as well as interpret data to understand the construction and performance of competitors and their carts. Accordingly, in this investigation, concerns associated with unfair competitive advantages helped in the promotion of student critical and reflective discussions related to planning and development of the equipment (James 2010) through the exploration of sports engineering and modelling.

For data collection, students were organized into four groups, two with eight and two with nine students each, in order to elaborate and develop modelling projects related to the designing and construction of roller carts in which they could participate in a race competition under equal conditions for the competitors. The data collection with regard to the design of the model of the roller cart and its construction was conducted from 29 May 2017 to 26 June 2017. Student groups developed modelling projects in 12 classes that were each 45 minutes long.

Quantitative and qualitative data were collected by using three activity modules related to the learning tasks through the modelling process. Quantitative data were organized and analysed by using descriptive statistics. Subsequently, qualitative data were quantified in order to develop two conceptual categories: *Modelling as a Learning Environment* and *Modelling and Sports*.

## 18.4 Results and Discussion Gleaned from Conceptual Categories

Mathematical modelling as a learning environment enables students to analyse and interpret data, to formulate and test hypotheses, and to verify the effectiveness of the elaborated mathematical models taken from their own reality. For example, 24 (70.6%) students stated that they used geometric concepts, measurement and transformation units, reduction scales, ratio, proportion, as well measuring instruments such as rulers, squares, compasses, and scalers to elaborate the geometric models of the roller carts.

Modelling, as we perceive it, is a process that is not a neutral or passive activity. In this approach, students in their groups designed a model and constructed their roller carts by learning how mathematical concepts were used in the preparation, analysis, and resolution of their models. Then, students chose a standardized model of the roller cart to be used in the race competition. Figure 18.2 shows the models of the roller carts developed by the students in each group.

Since there were minor differences between the elaborated models, the researchers asked students to exchange information with other groups in order to analyse and standardize their models. During the process of the standardization of the chosen roller cart, students in their groups decided to determine the measures of the bearings of their roller cart. Then, students developed and applied mathematical procedures such as how to use measurement units to identify and propose solutions

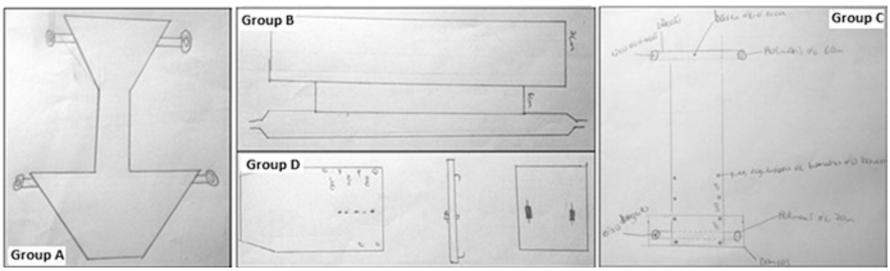


**Fig. 18.2** Models of the roller carts. (Source: Authors' personal file)

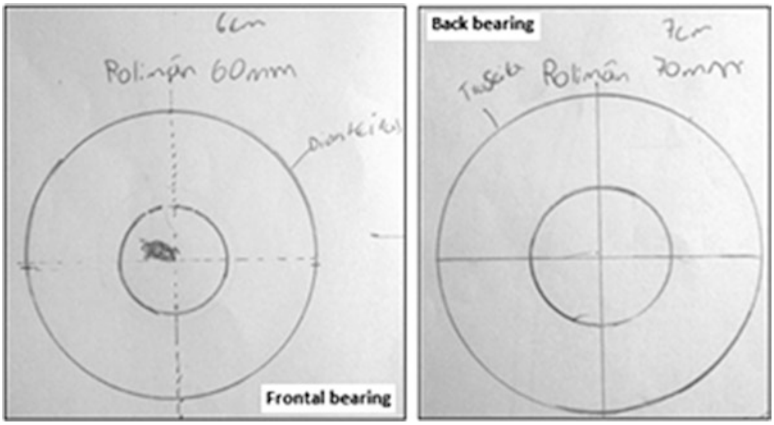


**Fig. 18.3** Models of the front and back bearings of the standardized cart. (Source: Authors' personal file)

to the construction of the roller carts. Figure 18.3 shows the models of the front and back bearings of the standardized cart, which were 60 mm and 70 mm, respectively.

During the mathematization process, one of the students said: "But 60 and 70 are big measures", and another student replied: "No, they are good sizes". Thereafter, the researchers realized that some students did not notice that the measurements were given in millimetres and explained about scales and the mathematical relation between millimetres and centimetres.

Later, in the development of the modelling project, during the validation of the measurement of the parts by the woodworker, students decided to change the size of diameter of the bearings to 70 mm in the front and 80 mm in the back of the roller cart. This decision was made because the thickness of the wooden parts was changed from 3 cm to 2 cm and students decided to maintain the same height of the standardized roller cart with respect to the ground as determined in the initial modelling project.

Students in their groups applied modelling to develop a standardized roller cart for the competition by using mathematical content to accomplish the proposed activities related to the design of the model and the construction of the roller carts. For example, one of the concerns of the students was to determine the dimensions of the roller carts that were suitable for the students, regardless of their height and size so that all of them could participate in the race. One of the students was considered as a reference for the development of this task because she was small. Then, this student positioned herself on two desks as if she was sitting on a roller cart so that students could determine measures of the length of the seat and the main axis. Next, students used cardboard to perform this simulation to facilitate the development of the measurements. Figure 18.4 shows the development of this simulation process.

Next, students drilled four holes in the main axis so that the seat could be adjusted in two different positions to allow all students in their groups to fit in the standardized roller cart for the race competition. According to the students' decision, these holes were drilled in the centre of the seat so that they were aligned with the back

**Fig. 18.4** Simulation process of the standardization of the size of the roller cart. (Source: Authors' personal file)

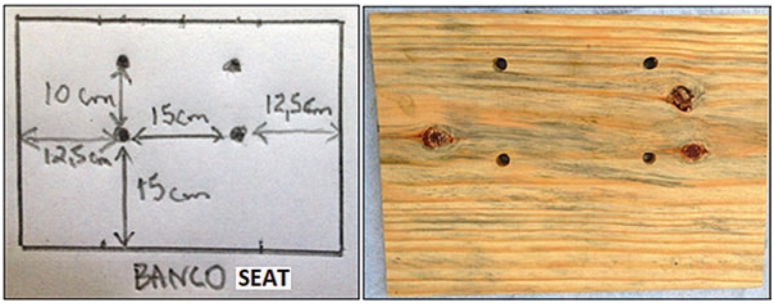


**Fig. 18.5** Model and wooden seat of the standardized roller cart. (Source: Authors' personal file)

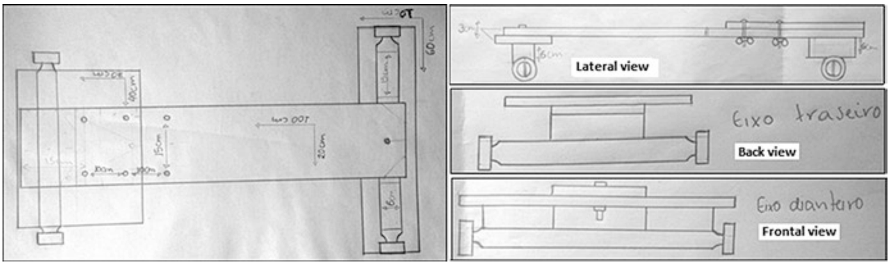


**Fig. 18.6** Standardized roller cart modelled by the students. (Source: Authors' personal file)

extremity of the centre axis of the roller cart when it is in its highest position. Figure 18.5 shows the model and the wooden seat of the standardized roller cart.

During the process of elaborating this model, students described, analysed, and interpreted the data collected about the dimension of the parts of the cart. Then, they sent their notes to the woodworker for the validation of their results. Figure 18.6 shows the standardized roller cart modelled by the students in all groups.

For example, 26 (76.6%) students affirmed that the standardization of procedures makes roller cart competitions fairer. Thus, one of the students argued that "all the roller carts are mathematically the same and what really matters is the preparation of the drivers and their dedication". According to Barbosa (2006), it is important that results obtained in this process are linked to the students' perceptions and reality.

In this study, mathematical modelling was considered a learning environment in which students inquired and investigated a phenomenon (model of a standardized roller cart). The students worked with real problems and used mathematics as a language for understanding, simplifying, exploring, and solving situations in an interdisciplinary fashion through mathematical modelling (Rosa and Orey 2015). To sum up, the students applied this pedagogical action when they observed the attributes of designing a model and constructing a standardized roller cart, verified if specific outcomes could be produced and reproduced, and understood how to use rules and norms to select different and efficient variables to manipulate and elaborate this mathematical model.

## 18.5 Final Considerations

The emphasis on data analysis by students in relation to problems they face in their own communities is one of the fundamental characteristics of mathematical modelling as a learning environment. For example, Rosa and Orey (2015) argue that the ongoing and developing critical perspective of students in relation to social conditions that influence their own lives and experiences helps them to identify common problems and collectively develop strategies to solve them.

In this study, the focus of mathematical modelling was to use data in a specific sport competition related to roller carts that have been initially created by the social, cultural, climatic, and economic influences in Brazil in which popular and diverse forms of competition arose and are still practiced. This presents a rational transformation because it involves critical analysis of sociocultural phenomena through the elaboration of mathematical models. In short, they learn to move away from high emotional arguments and focus on the data.

When learners explore problems taken from their own reality, they begin to study symbolic, systematic, analytical, and critical contexts by using mathematical tools developed and learned in a modelling-learning environment. In this context, modelling as a learning environment emphasized the role of mathematics in society as well as the function of mathematical models in solving everyday challenges. This approach helped students to move away from emotional arguments and to focus on, and then apply, data-based tools to build a model of a standardized roller cart for a race competition. Hence, this project incorporated a type of transformative learning that created conditions that helped the learners to challenge the worldviews and values they saw around them. Hopefully, this experience allowed them to reflect critically on these experiences in order to develop a data-based rational discourse in new opportunities and contexts.

Mathematical modelling is, as we use it, a teaching methodology that focuses on the development of students' criticality and reflexivity in order to engage them in contextualized activities that enable the development of a deeper and increasingly more active involvement in the constructions of social significance of the world of the learners (Rosa and Orey 2015). Modelling as a learning environment is based on the comprehension and understanding of reality and the generated data. When we borrow systems from reality, students begin to study and analyse them symbolically, systematically, analytically, and critically in order to make informed decisions based less on emotion and more on data.

## References


Barbosa, J. C. (2006). Mathematical modelling in classroom: A critical and discursive perspective. *ZDM Mathematics Education, 38*(3), 293–301.

Brothwell, A. (2016). *What is sports engineering?* Sheffield: ISEA.

Creswell, J. W., & Plano Clark, V. L. (2007). *Designing and conducting mixed-methods research*. Thousand Oaks, CA: Sage.

D'Ambrosio, U. (1999). Literacy, matheracy, and technocracy: A trivium for today. *Mathematical Thinking and Learning, 1*(2), 131–153.

James, D. M. (2010). *The ethics of using engineering to enhance athletic performance*. In Proceedings of the 8th conference of the International Sports Engineering Association (pp. 3405–3410). Vienna: ISEA.

Lewis, M. (2003). *Moneyball: The art of winning an unfair game*. New York: W. W. Norton & Company.

Malkevitch, J. (2017). *Mathematics and sports. Feature column: Monthly essays on mathematical topics*. Providence, RI: American Mathematical Society – AMS.

Noubary, R. (2010). Teaching mathematics and statistics using tennis. In J. A. Gallian (Ed.), *Mathematics and sports* (pp. 227–239). Washington, DC: The Mathematical Association of America MAA.

Orey, D. C. (2011). *The math trail at California State University, Sacramento*. Sacramento, CA: CSUS. Retrieved July 30th, 2017, from https://sites.google.com/site/mathtrailcsus/.

Rosa, M., & Orey, D. C. (2007). Cultural assertions and challenges towards pedagogical action of an ethnomathematics program. *For the Learning of Mathematics, 27*(1), 10–16.

Rosa, M., & Orey, D. C. (2015). Social-critical dimension of mathematical modelling. In G. A. Stillman, W. Blum, & M. S. Biembengut (Eds.), *Mathematical modelling in education research and practice: Cultural, social, and cognitive influences* (pp. 385–395). New York: Springer.