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On the shoulders of giants: A PCTO experience about Guido da Vigevano

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Summary. — This report shows the results of a P.C.T.O. (Course for Transversal Skills and Orientation) experience, carried out entirely in DAD (Remote Learning) in the s.y. 2020/2021, involving 100 students from the Scientific and Artistic Secondary School of I.I.S. Cellini, Valenza (AL), Italy. The didactic experience aimed to introduce and spread the important figure of Guido da Vigevano, scientist, doctor and engineer of the 13th/14th century. The entire formative path focused, in particular, on the work *Le macchine del re* by G. Ostuni, a critical study of the manuscript by Guido da Vigevano *Texaurus Regis Francie*, which was analyzed by the students from a historical, architectural, engineering, physical and artistic point of view, and encouraged them to think about overcoming the traditional dichotomy existing between humanities and scientific disciplines.

1. – Introduction

This report shows the results of a P.C.T.O. (Course for Transversal Skills and Orientation) experience, carried out entirely in DAD (Remote Learning) in the s.y. 2020/2021, involving 100 students. The project was conceived after attending an Applied Mechanics lecture, held by Professor C. E. Rottenbacher at the Faculty of Engineering, when I heard the name of Guido da Vigevano for the first time. So I decided to carry out the curricular training activity scheduled by my course in Industrial Engineering at the University of Pavia about this topic. Thanks to the interweaving of teaching and analysis, we tried to bring students closer to the academic world and to the world of research. Dealing with this kind of work with 17-18 year olds allowed me to deepen two aspects of particular interest. Firstly, the students had the opportunity to face a topic which is not part of the usual teaching program carried out in the classroom: that is to grapple with an operational and interpretative problem concerning a historical topic which can only be carried out in an interdisciplinary way by combining all the disciplines and knowledge acquired over the years during the formative process. Secondly, the specific project developed with

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the contribution of the students allowed them to engage in a text and drawings dating back to over 600 years, making use, even though in a rigorous scientific context, of all the creativity, imagination and freedom of thought of their age in order to learn to see with different eyes what apparently would seem incomprehensible.

2. – The Method

The whole project was based on *Le macchine del re* [1], written by G. Ostuni, containing the transcription, translation and commentary of the code lat. 11015 in the National Library of Paris. The students of classes 4A, 4B and 4E attending the Scientific Secondary School of I.I.S. Cellini, were divided into 11 groups. We entrusted a chapter to each one, showed in table I, with the exception of chapter XII.

Each group had the support of their teachers of Mathematics, Physics, Art and Design, Philosophy and History, Italian Literature, Latin. Each class also had a reference teacher: Matteo Torre (Mathematics and Physics), Alice Marchisio (History) and Simone Oliveri (Art and Design). As it appeared to be a very complex project, we decided to support the students with guidelines they could use as references. The assignment consisted of 15 questions, listed in table II, that helped them to deal with the analysis in an orderly manner.

In the first step of the analysis we asked the students to work on questions No. 1, 2 and 3, whose aim was to begin to approach the students to the problem with a first degree of difficulty. Then we continued with questions 4–10, which brought the level of analysis to a higher level, since the students were expected to have begun to understand the content of their own chapter more deeply. Finally, the outline ended with questions 11–15, with which we led the students to think not only about the contents of the chapter but also about transversal aspects. Together with the activities of the Scientific classes, some students of the fourth and fifth year of the Artistic secondary school of the same institute were involved. Under the guidance of their teacher Paolo Mazzucco (Design Disciplines), they performed a more accurate analysis from a figurative and technical point of view. Table III shows the division into groups.

TABLE I. – *Chapters of the Manuscript assigned to each Scientific group.*

Group	Chapter	Device	Original title
1	I	Drapes and protective devices	*"Qualiter bellantes debeant..."*
2	II	Platform-pole	*"De modo faciendi perticam..."*
3	III	Bridge for walls	*"De modo faciendi pontem..."*
4	IV	Ladder tower with bridge	*"De modo bellandi turres"*
5	V	Fortified ladder	*"De modo faciendi scalas..."*
6	VI	Siege tower with lifting platform	*"De modo faciendi castrum..."*
7	VII	Floating bridge (temporary)	*"De modo faciendi pontem..."*
8	VIII	Boat and a second boat designed like a floating bridge	*"De modo faciendi naves..."*
9	IX-X	Floats for horsemen and infantrymen	*"De modo equitandi..."* - *"Quomodo pedites..."*
10	XI	Battle waggon	*"De modo faciendi carrum..."*
11	XIII	*"Panther"*	*"... de modo faciendi artificia ..."*

TABLE II. – *List of questions provided to students for the analysis of the Texaurus chapters.*

	Questions
1)	How is the chapter structured?
2)	Are there any figures in the text?
3)	Are there any drawings attached?
4)	Are there any terms used to label specific elements? Are these terms repeated in the text in different ways?
5)	Is any mechanism described? Which? How?
6)	Are there any constructive solutions?
7)	Are there any references to materials?
8)	Are there any material processing techniques?
9)	Are expert craftsmen mentioned to entrust the work?
10)	Are there any references to units of measurement?
11)	Are other techniques or scientific knowledge of any kind described?
12)	Are alternatives or developments of the device proposed?
13)	What is the purpose of the device?
14)	How is the device used or operated?
15 optional)	Is the device suggested by Guido found in manuscripts or later printed works?

TABLE III. – *Chapters of the Manuscript assigned to each Artistic group.*

Group	Chapters	Devices
1	II–VIII	Platform-pole - Boat
2	III–IV	Bridge for walls - Ladder tower with bridge
3	V–VI	Fortified ladder - Siege tower with lifting platform
4	VII–XIII	Floating bridge (temporary) - *"Panther"*

The students of the art classes worked on the following aspects:

- analysis of the drawings present within the chapters;
- creation of scale drawings, such as orthogonal projections and axonometries, with particular attention to keeping the result as faithful as possible to the description contained in the original text;
- realisation of 3D rendering with the use of Rhinoceros [2], which completed the process of building the machines and understanding the manuscript, as far as possible.

At the end of the formative/projectual course, an online conference was held, during which each group was able to share the results of their work with all the participants in the project.

3. – Guido da Vigevano and *Texaurus Regis Francie*

There is little information in our possession about Guido da Vigevano's life. Born in Pavia, about 1280, he studied medicine, probably in Bologna. During the struggles

between the Guelphs and Ghibellines he was among Emperor Henry VI's suite and, in 1318, his presence is attested in Pavia, where he actively participated in political struggles. In 1335 he was in France as Queen Joan of Burgundy's doctor. In the same year he devoted the *Texaurus Acquisicionis Terre Sancte*([1]) to Philip VI of Valois, the text was handed over in three manuscripts: code lat. 11015 in the Bibliothèque Nationale in Paris, its nineteenth-century copy, code G.V. 9 in Turin's University Library and code Mil. mss. (4°) in the Yale Center for British Art. Starting from 1349, the year of the very violent plague epidemic that struck Europe and also Paris, Guido's name is no longer recorded in documents.

Guido's work is divided into two parts: *Modus Acquisicionis Terre Sancte*([2]), on which the project was focused, and *Liber Conservacionis Sanitatis Senis*, dealing with a medical topic. In the former, within 13 chapters, Guido describes and represents useful devices for the conquest of the Holy Land. In the latter, he gives the king advice about how to stay healthy and how to protect himself from poisons.

The first difficulty that Guido wants to overcome is the transport of his machines, as he repeatedly emphasizes in the text: "*being tiring to carry heavy loads overseas, like these devices*" (l. 3-4, p. 90, here and in the following of the paper every reference is to *Le macchine del re*). With God's help he claims to be able to design all the devices to conquer the Holy Land, both by water and by land, they will be easily transported on horseback and assembled without wasting time. The basic idea is to have all the components necessary for the machine construction available, disassembled and taken on horseback. In this way, it is possible to build what is needed only when it has to be used and, when the army has to resume walking, it is possible to disassemble the machine and to reposition all the pieces on horses to proceed with the transport. Speaking in modern terms, Guido conceives all his machines to be built in batches, assembled on site and also designed so that the pieces of a construction can be adapted and used for another one [3]. It is a way of thinking of an advanced craftsman, having a clear idea of the mass production of pieces.

From the analysis of Texaurus, the idea emerges that Guido had precise knowledge of the machines he describes and provides the main aspects of each one, but leaves the specific and contingent construction problem to be solved by the specialist craftsman in the field (*"videbitur operanti"*, C. 6, l. 30, p. 122). Furthermore, Guido expressly makes use of complete drawings at the end of every chapter:"*I will explain this, point by point, in the following chapters and after every chapter I will always give a clear picture"* (l. 12-13, p. 90).

The *manifestum exemplum* is a drawing, which represents in its entirety the machine that has just been described in the chapter. Two examples are shown in fig. 1.

The drawings belong to an era far from ours in which there was still no use of perspective (Giotto was a contemporary of Guido) and of the axonometric constructions that would be developed in the following centuries. We would make a huge mistake if we tried to interpret them on the basis of modern design rules and conventions, and precisely this has prevented scholars from revealing all the richness and value of these representations up to now. To our modern eye, the drawings seem strange and indecipherable because there is no perspective, and there is no axonometric construction. According to Guido,

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([1]) *Texaurus Regis Francie acquisicionis terre sancte de ultra mare nec non sanitatis corporis eius/ et vite ipsius prolongacionis/ ac etiam cum custodia propter venenum.*

([2]) *Modus acquisicionis terre sancte Christi nomine invocato Regi Francie intitulato.*

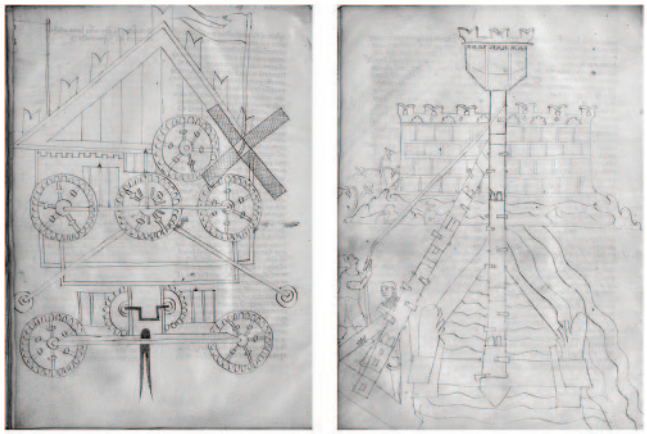


Fig. 1. – (a) Battle waggon (Ms. Yale, fol. 16v), (b) platform-pole (Ms. Yale, fol. 3v).

the picture was intended to show the function of the machine in its entirety without the rigorous construction detail that would have been clearly deducible in the field by the master craftsman employed in the actual construction. Another original aspect of *Texaurus* concerns the presence of drawings interspersed in the text, which makes it the most ancient testimony of this kind that has come down to our days. The adoption of text and figures is fundamental to make it easier for the reader to understand the chapter: in Guido's mind, text and image become a single and inseparable object. The text without the image would be incomplete and, at the same time, the image without the text would be incomprehensible. It can be observed how Guido, with the adoption of this procedure that could be summarised as *describe and draw* [4], anticipates Leonardo da Vinci by about 150 years in emphasizing the importance and the need to overcome the use of the single word to obtain a more effective communication. 150 years later, Leonardo da Vinci wrote [5]

E tu che vogli con parole dimostrare la figura dell'omo con tutti li aspetti della sua membrificazione, removi da te tale openione, perché quanto più minutamente descriverai, tanto più confonderai la mente del lettore e più lo removerai dalla cognizione della cosa descritta. Adunque è necessario figurare e descrivere.

And you who think to reveal the figure of man in words, with his limbs arranged in all their different attitudes, banish the idea from you, for the more minute your description the more you will confuse the mind of the reader and the more you will lead him away from the knowledge of the thing described. It is necessary therefore for you to draw and describe.

4. – Units of measurement

The importance of units of measurement is undisputed. Since ancient times, humans have sought increasingly refined methods to associate a number, a value with a certain physical quantity. Thus the need to create a reference to meet our requirements arises. Unlike the universal units of measurement that we all know today, there were only local units of measurement. This means that, although each of them was called with

the same name, there were slight differences according to the territory and the city. These measurements are deduced from the human body, which explains why they are called anthropomorphic units of measurement. As for lengths, the Egyptians used the cubit as a basic measure, which indicates the measurement of the forearm. Greeks and Romans, on the other hand, had the foot as a base. The mediaeval units of measurement, to which Guido refers, descend directly from these civilizations, in particular from the Romans. Throughout the manuscript they are frequently used to describe the shape of the components. Since there were not yet technical notations to indicate accurately which dimension they referred to (length, width, thickness, diameter), particular terms are used:

- length measurements: *"wood 1 arm and a half long"* (C. 5, l. 11, p. 118);
- width measurements: *"plank 1 arm wide"* (C. 7, l. 2, p. 130);
- thickness measurements: *"laths of woods 1 finger narrow"* (C. 7, l. 3-4, p. 130);
- circumferential measurements: *"trunks as big as a man's leg"* (C. 2, l. 3-4, p. 96);

Whenever it is necessary to provide a slightly different measure from the predetermined one, Guido uses adjectives to make the reader understand the modification to be made. For example, to indicate a measure greater than an arm or a finger we find *"an arm and more"* (C. 5, l. 2, p. 118) or *"a large finger"* (C. 3, l. 9, p. 106) while, for smaller measures we find *"a small arm"* (C. 6, l. 5, p. 122). Another strategy that Guido uses is a method of indirect deduction of the measurement starting from the knowledge of the size of another component. This happens for example to refer to the size of the holes, whose diameter is not given several times. If we know how the rope to be inserted is made, consequently it is possible to make a hole with its dimension: "*make 8 holes in each axis [...]. The axis are joined by means of 4 ropes, a large finger wide*" (C. 3, l. 5-9, p. 106). For the study of the measures present in the manuscript the text by Zupko [6] was very helpful. We could find varied units of measurement and the values relating to different Italian cities. Below I will introduce some evaluations that have been made for each unit of measurement.

4˙1. *Arm (brachium).* – The most common measure throughout *Texaurus* is the *arm*, so we will start with it.

> *"Take slight, thin planks, five arms long, one arm wide [...]." (C. I, l. 17 p. 92)*

With *arm* we mean the length measured from the tip of the middle finger to the elbow and on the basis of various testimonies we can say that it is about 60 cm. Sometimes the *arm* is used not only to indicate a measure of length but also for diameter measurements, for example:

> *"Take eight square pieces of wood [...] as big as an arm [...]." (C. VI, l. 11-12 p. 122)*

In this case, the measurement has to be understood as transversal, referring to the cross-section of the wood. Considering 32 cm as the average circumference of a man's arm, we obtain a value of the diameter of about 10 cm.

4˙2. *Semisse*. – From a first reading, we could intend the *semisse* as the Roman coin and consequently take the size of the diameter as a value to be attributed to this measure. However, we would soon realise that it is too a small measure for the applications in which it is used.

> *"To make the parapet of the bridge, two iron rods are fixed to a half-axis from the edges [of the boards] at the extremities made in this way [...]." (C. VII, l. 22-23 p. 130)*

The Treccani vocabulary [7] comes to our aid, and we can learn that it is a measure of length widespread in northern Italy, corresponding to the size of the fist with the thumb up. To this measure we can attribute a value of about 15 cm. Another interesting interpretation, provided by a student, is the analysis of the word from an etymological point of view. The word semisse can be divided in two parts: *semi-*, from the Latin meaning *half*, and *-as*, meaning *entire, one*. The resulting composed word means *half of the entire*, which could make the magnitude of this measure clear. Considering that for the Romans the reference unit of measurement was the foot (*pes*), which corresponds to about 30 cm, the half of the whole obtained is about 15 cm.

4˙3. *Man's leg (gamba hominis)*. – *The man's leg*, or even the thigh, is a measure used primarily to indicate diameters and sections.

> *"Take trunks of good wood, each one arm and two half-axes long and large, as big as a man's leg [...]." (C. II, l. 2-4 p. 96)*

Considering 50 cm as an approximate measure of the circumference of a man's thigh, we obtain a value of the diameter of about 16 cm. The result obtained is acceptable for the diameter of the objects under discussion but, following some evaluations, it could be preferable to consider this measure as a diameter of 20 cm.

4˙4. *Finger (digito)*. – The smallest measure that Guido gives us in his manuscript is the finger, which is mostly used to indicate the dimensions of holes, strings and the thickness of boards.

> *"Make two bottoms with larch boards, a finger thin [...]." (C. II, l. 34-35 p. 100)*

It is a measure inherited directly from the Romans, who defined the *digitus* as 1/16 of a foot. A foot's value is about 30 cm and we obtain an effective measure of 1,85 cm. For our applications it is an excessively precise value that Guido and the mediaeval artisans would never have considered, therefore it is convenient and appropriate to round this measure to 2 cm.

4˙5. *Span (spana)*. – The last measure we consider, also taken from the hand, is the *span* and in this case it is a length measurement used mainly to define relative widths or distances between components.

> *"Place two thin boards, a span wide [...]." (C. VIII, l. 6-7 p. 136)*

With *span* we mean the distance between the tip of the thumb and the little finger of the hand extended, with the fingers spread as far as possible. This measure was also used by the Greeks and it was equivalent to 2/3 of the foot or half a cubit, or 22 cm in the Athenian system and 23 cm in the Alexandrian system [8]. In our case, for convenience and simplicity, it might be appropriate to assign it a value of 20 cm.

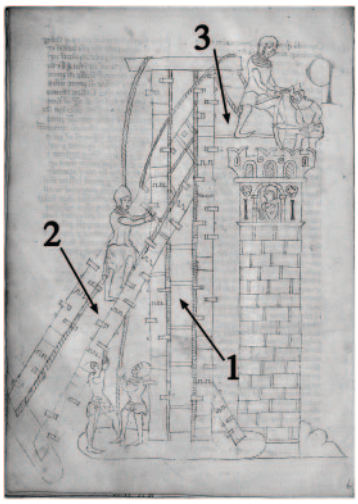


Fig. 2. – Ladder tower with bridge, Ms. Yale fol 5v.

5. – Chapter IV, *De modo bellandi turres*

Among all the chapters under study, for reasons of space, within this paper I will present only Chapter IV. This chapter describes the construction of a device that allowed soldiers to reach the top of walls and towers. To make this machine correctly, it is necessary to know the exact height of the tower. For this reason, Guido opens the description of the chapter with an accurate explanation of a method for measuring the height of a building. From the figure present in the Yale manuscript (fig. 2), we can distinguish 3 structures.

1) Vertical ladder, internal ladder facing the tower;

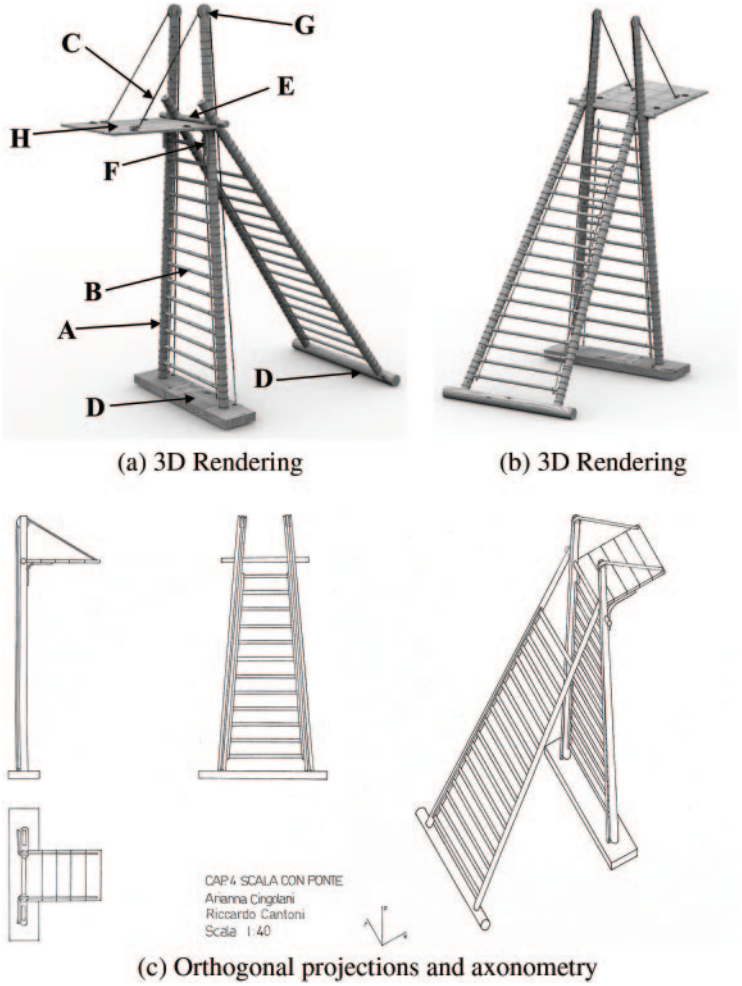
2) Oblique ladder, external ladder facing the army;

3) Bridge.

The two ladders are made in the same way with the components that will be listed later; the only difference is that the oblique one must be longer in order to compensate

TABLE IV. – *Main components of the ladder tower with bridge.*

Reference	Component	Material	Quantity
A	Post made in sections	Wood, Iron	4
B	Rungs with hoops	Wood, Iron	Proportional to the height
C	Rope	Not given	6
D	Ladder's base	Wood	2
E	Axle	Wood	1
F	*"Dubio"*	Wood	2
G	Pulley	Wood, Iron	2
H	Bridge	Wood, Iron	1



(a) 3D Rendering (b) 3D Rendering

(c) Orthogonal projections and axonometry

Fig. 3. – 3D Rendering and drawings of the ladder tower with bridge.

for the inclination. The bridge located at the top of the ladder is not described in detail in this chapter, as it has to be built exactly in the same way as already described in Chapter III. Once the entire device has been built, it is time to place it near the walls. First, the base of the ladders is positioned inside the moat, whether there is one, and then the ladders are raised. During this manoeuvre, the bridge must be kept raised by means of ropes, so that once the ladder is positioned, it can fall on top of the tower. To protect soldiers from enemy attacks, Guido recommends using the drapes described in Chapter I. Table IV lists the components to create the entire structure, which can also be found in fig. 3.

6. – Conclusions

Having had the possibility to focus my university internship on a project like this is a unique opportunity. Such an ancient work contains endless information, directly or

indirectly obtainable through a complete analysis from all points of view. The chapter subdivision allowed each group to work independently and to hand in their results within the pre-established deadlines. The students faced a very particular school-work training project, an unusual problem, with the help of their spirit of initiative, different attitudes, and different interests and abilities. Finally, the various multidisciplinary applications would allow them to finish their studies bringing the products of their work to the final exam. The project was very interesting but not so simple. The first difficulty was found in the language and in the way in which the devices are described. The centuries that divide us mean that some basic knowledge of a medieval man has been lost and the working method is totally different, consequently it was not always possible to make absolute decisions and therefore we tried to give a more faithful interpretation, considering the possibilities of the time. After the analysis with Scientific secondary school students, it was the turn of the students of the Art secondary school, with whom we performed the creation of drawings and renderings of the machines. When the interpretation part of the text was already over, apparently it seemed that everything would be simple. It was a question of gathering all the pieces that had only been conceived from a theoretical point of view but, as it often happens in reality, compromises had to be found. This happened, for example, in the choice of relative distances between elements that were not specified, as thicknesses, hole diameters, or even materials. What we obtained was very satisfying and, for some machines, being able to see the device come to life in a three-dimensional environment enhanced its grandeur in such a way that for a moment you could try to perceive what it would have been like to be in front of such imposing devices.

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I wish to thank everyone who took part in this project, beginning from the students, the teachers and the school leaders, who have allowed its accomplishment. Furthermore, I wish to acknowledge Prof. Rottenbacher for giving me the opportunity to work on this topic, Prof. Torre for encouraging me to attend the SIF 107th National Congress, and Prof. Credali for the support provided in translating this paper into English.

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