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Mathematics Education in a Digital Culture

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Abstract
This article discusses the teacher’s training that can help schools to become better at their time. Meeting this challenge involves understand the lifestyles of people immersed in digital culture. We investigated the authoring process of digital learning materials developed by mathematics undergraduates at Federal University of Uberlândia, Brazil. The chosen productions to present in this paper were: “Educational robotics: a study of the Ferris wheel” and “Rolling knowledge”, both deal with the study of mathematical based on Ferris wheels. These productions are located in three sets of interwoven theoretical and experimental knowledge by simulation: Theme, Mathematical Model and Information Technology and Communication (ICT). The connection between these three areas is based on decisions, understanding variables and learning previously unimagined perspectives. In other words, simulation between themes, mathematical models and ICT are the act of choosing “paths” in mathematical knowledge. We conclude that, in a digital culture, the concept of mathematical modeling is actually a simulation environment in which interaction is simulated in four dimensions: Dialogical, diverse, dated and dynamic. We have also to understand that simulation is one of the ways to work with mathematical modeling in the digital culture of a teacher.

Keywords: Teacher’s Training, Mathematical Modeling and Simulation.

1. Introduction

The importance of digital technology in our lives is undeniable. Thus, is necessary to understand the meaning of the word digital. In technical terms, the word digital is the basis of change a technology represented by an analog number. This is represented by an analogy of what happens between a physical phenomenon and a predetermined numerical quantity. An example of this is the speedometer needle that indicates the velocity of an automobile. However, for technologies represented by digital numbers, operations are performed directly by symbols, called digits, such as:

> […] the digital watch, which provides the time of day in the form of decimal digits which represent hours and minutes (and sometimes seconds). As we know, the time of day changes continuously, but the digital watch reading does not change continously; rather, it changes in steps of one per minute (or per second). In other words, this digital representation of the time of day changes in discrete steps, as compared with the representation of time provided by an analog watch, where the dial reading changes continouslys (Tocci; Widmer; Moss, 2007, p. 2, our translation).

The word digital can describe, in discrete terms, numerical, linguistic and other types of phenomena. However, in the last 60 years, the word has become synonymous of technology. To some extent, "computer technology" and "digital technology" have become interchangeable. Computers are digital because they manipulate and store data in digital format, binary, zeros and ones. However, the term digital has come to mean much more than simply discrete data or machines that use data (Tocci; Widmer; Moss, 2007).

It can be said that digital is synonomous of a set of virtual simulations, instant communication, ubiquitous media and global connectivity that constitutes much of our contemporary experience. It alludes to the wide range of applications and forms made possible by digital technology. This includes virtual reality, digital special effects, digital cinema, digital television, electronic music, computer games, multimedia, the Internet, the World Wide Web, digital television, the Wireless Application Protocol (WAP) as well as various artistic and cultural responses to the ubiquity of digital technology such as Cyberpunk films and series, Techno and post-pop music, net.art, new typography, etc. It also evokes the world of capitalism dominated by high-tech wires, companies like Microsoft and Sony and the so-called "dot-com" Internet-based businesses, which, for a time, seemed to represent the ideal of XXI century business model. In general, the incomprehensible complex of corporate business, enabled by high technology that operates on a global level and at times, seems to have more power than nation-states. This also suggests other digital phenomena, such as new paradigms of computer control, supposedly clean "virtual wars", genetic mapping and the Human Genome Project, in which the transmission of hereditary disease presents its very own digital question. Thus, the seemingly simple term digital defines a complex set of phenomena (Gere, 2008).

From this point of view, Gere (2008) concludes that there is a distinct digital culture where the term digital can represent a way of life particular to a group or groups of people in a given period of history. Understanding culture as a keyword,

> [...] essentialy a semiotic one. Belivieving, with Max Weber, that man is an animal suspended in webs of significance he himself has spun, I take culture to be those webs, and the analysis of it to be therefore not an experimental Science in search of law but an interpretive one in search of meaning. It is explication I am after, construing social expressions on their surface enigmatical. But this pronouncement, a doctrine in a clause, demands itself some explication (Geertz, 1989, p. 4, our translation).

In this approach, culture is understood as an interpretive science in search of meanings that involve texts, sounds, images, light, colors, shapes and gestures. These are perceived, stored and disseminated through the cognitive function of memory that is collectively structured (Alves, 2001, p. 114).

From this perspective, there are two markers of contemporary digital culture. Digitality is the first marker because it includes systems of signification and communication that most clearly demarcate our contemporary way of life (Gere, 2008). Simulation is the second marker because at the foundation of computer culture is the idea of constructed worlds, "governed by rules." A culture of rules, because in contemporary society symbols are the purest act of imitation (Alves, 2011).

Immitation defines ways of thinking, acting and solving problems. Problems are solved in digital culture by hands-on experience which Papert (1985) claim is one of two ways to solve problems. Unlike analytical, this hands-on problem solving is based on finding solutions by testing and playing. These complex interactions and dialectic commitments between these two elements as well as technical and scientific discourses on information systems, avant-garde art, utopian counterculture, critical theory and philosophy, and even subcultures such as punk, are what produce digital culture (Gere, 2008).

However, the history of computers in mathematics education is very short, especially compared to how long it took for our current systems (analog and digital) to evolve. Thus, it is not not surprising that computer representations of mathematical expressions have not reached the same level of maturity, eventhough in a wider mathematical panorama, this change is happening speedly. However, from a pedagogical point of view, the norms and routines established in curricular approaches, teaching methods, learning and teaching materials still require a radical rethinking in light of what technologies can encourage their users do, think and share.

According to Noss (2002), the digital culture we live in is a small sliver of a set of mathematical models. A world where newspapers and television screens are flooded with statistical diagrams, and a culture in which more and more artifacts have computational elements that hide pieces of mathematical knowledge.

Noss’s (2002) and Papert’s (1985) reviews notes show an increasing need for research that permeates digital and mathematical culture, especially in teacher’s education. Teacher’s training is a critical moment to reflect on mathematics education, since

> Critically thinking about the practice of today or yesterday allows us to improve future practice. Theoretical discourse, which is a necessary part of critical reflection,

> has to be so concrete that it could almost be confused with actual practice. Epistemeology should not be distanced from practice, but brought as close as possible (Freire, 2006, p. 39, our translation).

It has been understood that in order to make a school the best of its time, it is important to deepen research on teacher's training within the context of digital culture.

> Education is not just an institutional and instructional process, but also an investment in the education of people whether in the particularity of the personal pedagogical relationship or the collective social relationship. Interaction with the teacher is universal and insubstitutable while keeping in mind the educational capacity of people (Severino, 2011, p. 633, our translation).

Thus, this text will discuss how to teach mathematics within digital culture and will consider hands-on mathematical models that can be manipulated and transform education at social and cognitive levels.

2. Methodology

A study of the reality shows many interrelated and independent fields. Nevertheless, closer inspection through actual practice shows a new reality "*where practice is inseperable from the sensitive aspects of this reality*. These aspects are likely to be the targets of our research." (Rey, 2005, p. 5, italics added).

This study was conducted with eleven students in the Teacher Certification course in Mathematics at Federal University of Uberlândia, Brazil. All of the students were attending the final year of the program and had already completed the Teacher's Training Workshop offered in the seventh semester.

This decision was made based on the the reflections of Melo (2007, p. 154). Melo claims that: "The *Teacher's Training Workshop* was significant because the students felt they had a greater opportunity to develop their *creative abilities*". According to this researcher:

> The educational practices that most stood out in the Mathematics degree, according to the students, were principally those developed in the teacher's training classes: [...] Teacher's Training Workshops I and II (60 hours each) [...] (Melo, 2007, p. 153, our translation).

It should be noted that this discipline was offered over two semesters until 2005. *Teacher's Training Workshop I* was focussed on elementary education and II focussed on middle school. In 2006, these two workshops were combined into a single *Teacher's Training Workshop* which was offered in the seventh semester of the degree.

We obtained our research data from student interviews and analysis of their digital productions. We consider these digital productions to be Learning Objects (LO) as defined by Wayne Hodgins in 1992. Hodgins was reflecting on teaching strategies while watching one of his children playing with Lego®. He realized at that moment that it was necessary to build educational blocks that could be connected and that would represent a range of educational content. He used the term "learning objects" to identify these educational blocks.

However, for us, Learning Objects (LO) can be understood as "any digital resource that can be reused for learning" (Wiley, 2000, p. 07). The LO can be created in any media or format and can be simple, such as an animation or a slide show, or complex, such as a simulation. Learning Objects use images, animations and applets, VRML (Virtual Reality) documents and text or hypertext files among others (Brazil, 2007, p. 20). In other words, LOs use the native elements of digital-culture oriented towards education and specifically, in this case, mathematics education.

Thus, we are striving to find the interaction between Mathematics and the Learning Object or to present mathematics through digital culture and find the mathematical model of the problem, which according to Skovmose (2007):

> [...] the concept of math modeling as a representation of reality is related to dualism, a perspective of two worlds. On one hand, we can work with mathematical concepts as part of the structured world, as suggested by formalism. On the other hand, we can work with the reality of the empiracle world. A mathematical model

> becomes a representation of part of this reality (Skovmose, 2007, pag. 107, our translation).

However, he cautions that, "We can make good and bad representations. The results of the model can be more or less adequate," and raise questions such as "What part of reality does this model address," "What math is used in building the model?" and "How well does the model represent reality?" We understand these questions, but we see them as ways to make a difference in the development of digital applications. As we have seen, if there is a mathematical model, there will be a way to combine Mathematics and Computers.

The mathematical model, therefore, represents part of a given reality. Thus, the plot is to describe the reality to which the model belongs and the characters who participate in the conflict (problem), which gives rise to the mathematical model. In summary, it is necessary to study what Biembengut and Hein (2003) called the Interaction step, in other words:

> Once the situation to be studied has been determined, a study should be made that is indirect (through books, specialized magazines, etc.) or direct, in situ (through field experience of experimental data obtained from a speacialist in the area). Although this step is divided into two parts - recognition of the problem-situation and familiarization - it does not follow a strict order, moving from one step to the next. The situation-problem becomes increasingly clear as one interacts with the data" (Biembengut; Hein, 2003, p. 13-14, our translation).

Students seeking teacher certification need to go beyond interacting with data and interact directly with the community where the situation-porblem occurs or to interact indirectly with the historical process of model creation.

3. Results

We are working to establish digital culture, not just as a novelty or challenge, but as a mean of expression for teacher certification students at the Federal University of Uberlândia. The increasing ubiquity of computers in the classrooms of this university and improving ability to use computers to create content and distribute educational materials for math education, show us that we are facing an increasingly complex set of digital technologies and paths for cultural production. Productions from the students reveal the interaction between professors, who possess theoretical knowledge, and the undergraduates, who understand digital technologies, and show collective reflection on and construction of knowledge.

From this point of view, we show two productions: "Educational robotics: a study of the Ferris wheel" and "Rotating knowledge." Both of these deal with the study of mathematical content based on Ferris wheel.

3.1. Educational Robotics: a study of the Ferris wheel

This production started in 2011 during research on Educational Robotics conducted by one of the teacher certification students in our study. The project was financed by the Research Foundation of Minas Gerais (FAPEMIG). "The project was developed on Fridays at 2 p.m. between 2011 March and October. This date was chosen because it was during free time and close enough to scheduled classes to avoid a long break between classes and the activities involving educational robotics" (Campos, 2011, p. 18)

This situation-problem production included:

> Assembling a Ferris wheel that could be used to explore the measurement of angles and segments, which is part of the seventh year of the elementary school curriculum (Campos, 2011, p. 10, our translation).

Two types of blogs were set up to facilitate the development of the project. One was to the participating groups and the other to the leader of the project. The first was used by the group of students in our study to post about their classes and project development. Two classes were set up for the creation and manipulation of blogs. Thus, even though the focus of the project was on Educational

Robotics, the students experienced digital inclusion. The second blog contained assembly instructions, trivia, instructional videos and useful links (Campos, 2011).

The theme of one of the studies was the "Ferris wheel". The mathematical study was based on regular flat geometric figure with computer designs for how to build the Ferris wheel (FIG. 01):

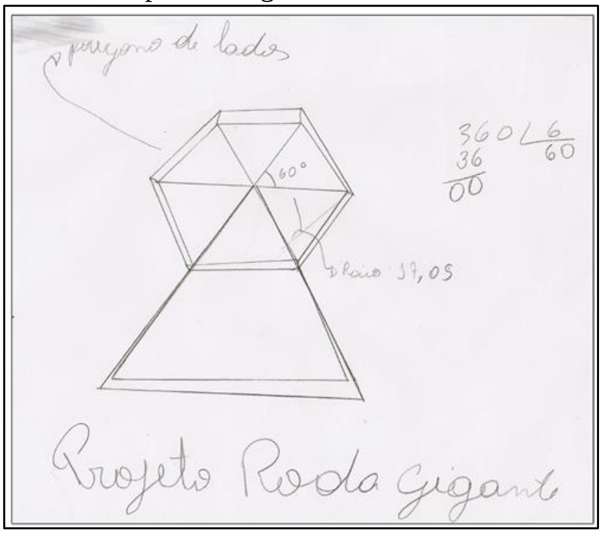

FIGURE 01 – Previous plan of the Ferris wheel by a student in the project using a computer application.
Source: Campos, 2011, p.14.

The mathematical model was based on the definition "A polygon is regular when it all its sides and angles are congruent" (Giovanni; Giovanni Jr., 2000, p. 115). Thus, the Ferris wheel chairs can be discussed as follows:

> *Angle α, between each chair of the Ferris wheel can be calculated by measuring from the center as follows: suppose we have a Ferris wheel with n evenly spaced chairs where* $n \in N : n \geq 3$. *Therfore, the internal polygon has n sides, which divide the circumference in n equal parts. Thus, it follows that:* $\alpha = \frac{360}{n}$
>
> (Campos, 2011, p. 14, our translation).

According to Campos (2011, p. 13), this activity "encourages discussion about the measurement of the internal angles of regular polygons. This discussion arises naturally during the lesson and is the apex of mathematical exploration in this context".

The Ferris wheel was constructed using a Lego Mindstorms kit and the choice of materials was based on practicality, ease and the small number of students. The greatest advantage of the kit, according to Campos, is that students can program the movement of the Ferris wheel. Thus, in addition to effectively using the mathematical model, students also use mathematical logic (Campos, 2011).

Thus, a Ferris wheel with six seats was constructed. However, the focus was not on the construction model of the seats, which were given, but on programming the wheel (FIG. 02):

FIGURE 02 – Ferris wheel. View of the front (left) and back (right), where the sensor that starts movement can be seen.
Source: Campos, 2011, p. 17.

A touch sensor was installed, FIG. 03, to give the idea of programming. When activated, the Ferris wheel (robot) started turning and just like at an amusement park, stopped after a period of time.

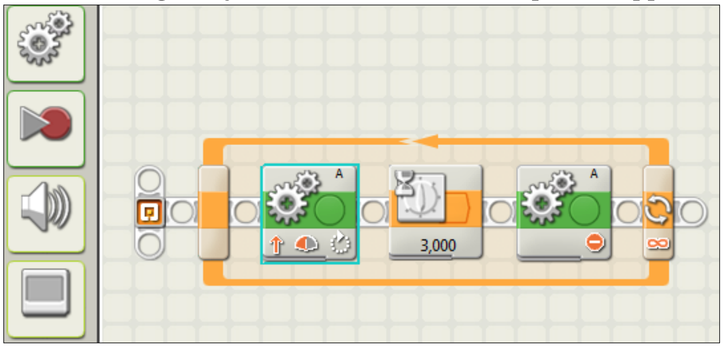

FIGURE 03 - *Lego Mindstorms* program for the Ferris wheel.
Source: Campos, 2011, p. 22.

Students were taken to an amusement park so that they could ride a Ferris wheel and discuss its mathematical elements. Afterwards, the students were expcted to program the Ferris wheel to rotate twenty times.

One of these programs (FIG 03) stood out from the others and functioned as follows: after activating the touch sensor, the Ferris wheel rotated 60º (the angle between seats on a Ferris wheel with 6 seats), paused three seconds, rotated another 60º and then paused for another three seconds. This process was repeated six times, after which the Ferris wheel rotated without stopping. The students programmed the Ferris wheel this way because they had experienced how a real Ferris wheel works. This observation period was fundamental to their understanding of the movement that they would later describe (Campos, 2011).

This led to the following situation-problem:

> If the time it takes for one rotation is known, how do we calculate the time it takes to rotate from one to the next chair? (Campos, 2011, p. 32, our translation).

One of the teacher certification students promptly responded, “just divide by six”. Thus, the structure of a Ferris wheel and the process of manually constructing and programming it allowed the students to solve the situation-problem.

3.2. “Rotating knowledge”

The second production was developed in the second half of 2010 as part of the "Teacher’s Training Workshop" of the mathematics undergraduate degree at the Federal University of Uberlândia.

The production was result of a series of course topics: Analyzing learning objects, Presenting and producing a Teacher's Guide and a roadmap for creating learning objects and Implementating learning objects. At the conclusion of these topics, the students had produced the learning object, which was then used as an end of course assessment tool.

This produced the following situation-problem: “What is the shape of the curve formed by a chair on a Ferris wheel?”[1].

This situation-problem is grounded in a trigonometric model:

$y = a * \sin(x)$,

where

a: is the radius of the Ferris wheel

x: is the time the Ferris wheel rotates

y: is the amplitude, or distance from the resting posisiton

This was then transformed into a computer program using *ActionScript 3.0*[2] (FIG. 04).

---

[1] Learning Object proposed by a student in the Mathematics Teacher Certification Course.

[2] *Adobe Flash*.

```
262 //construção da curva;
263 function atualizaCurva (e:Number) {
264     //bola1.visible = true;
265     bola1.x = numArray[e][0];
266     bola1.y = numArray[e][1];
267     //
268     if (e < Number(numArray.length)) {
269         curva.graphics.moveTo (numArray[e-1][0],numArray[e-1][1]);
270         curva.graphics.lineTo (numArray[e][0],numArray[e][1]);
271     }
272
273 }
274
275 //funçÃO
276 function valorFuncao (numX:Number):Number {
277     return (raio*Math.sin(numX));
278 }
279
```

FIGURE 04 – Code implementation of mathematical model
Source: Alves 2012.

Note that line 277 of the code gives the form of the curve. Lines 267 and 270 are responsible for the coloring of the pixels. Thus, the code simulates the size of the Ferris wheel, its movement and the curve of one of its chairs (FIG. 05):

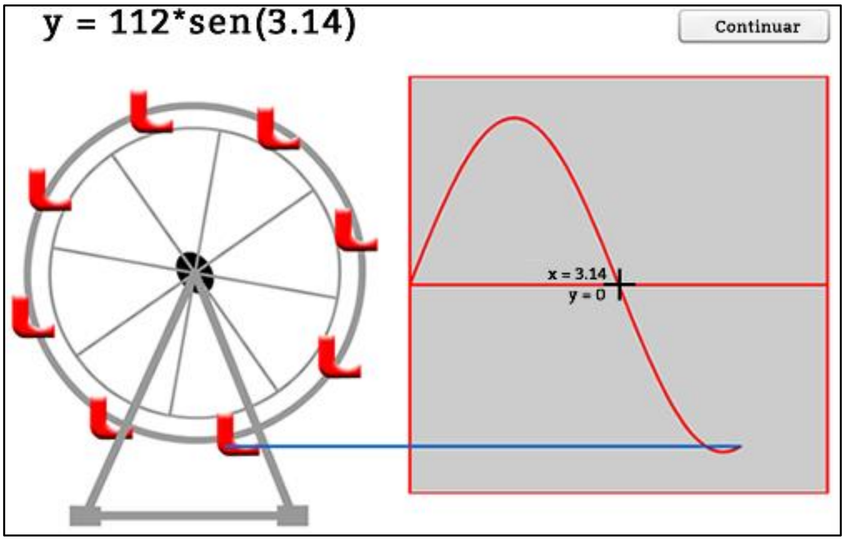

FIGURE 05 – Object simulation.
Source: Learning object planned by a student in the Mathematics Teacher Certification Course, 2012.

Notice that values for the time and amplitude appear as the user passes their mouse over the Cartesian plane. This learning object is available at http://rodandoconhecimento.blogspot.com/ so the visitors can use the object and also contribute by giving suggestions or even constructing other learning tools.

Developing learning tools with Adobe Flash helps teachers develop an understanding of mathematics by dynamically displaying multiple representations (numerical, algebraic, graphical, illustrated and verbal) either simultaneously or sequentially.

4. Discussions

According to Baudrillard (1981), representations of reality in contemporary society are obtained by pure simulation with no reference to reality. The author also indicates that simulation processes have evolved throughout human history. In his opinion, simulation is neither true nor false, but a deterrent machine staged to regenerate in the opposite plane of real fiction, which "is characterized by a precession of the model, of all the models based on the merest fact – the models come first, their circulation, orbital like that of the bomb, constitutes the genuine magnetic field of the event" (Baudrillard, 1981, p. 26).

Such wording makes it clear that simulation, whatever it might be, is the intentional representation of a social group. From that point of view, Skovsmose (2007, p. 107) claims that we never stop to ask ourselves: "What part of reality is the mathematical model addressing," "What math is used in building the model?"," And how well does the model represent reality?" Thus, the trust people put in computer simulations depends on the validity of the simulation model. Consequently, verification and validation are of crucial importance in the development of a computer simulation.

Another important aspect of computer simulations is the reproducibility of results. It means that a simulation should not provide a different answer for each run. This may seem obvious. Nevertheless, an important aspect of stochastic simulations is that random numbers should actually be random seminumbers. An exception to reproducibility would be humans in loop simulations such as flight simulators and computer games. Here, humans are part of simulations and therefore influence the result in a manner that is difficult, if not impossible, to reproduce exactly (Batrinca; Raicu, 2010).

These perspectives allow us to state that understanding how simulations function numbs the senses and reality, or even people's confidence in its validity. It is necessary to extend this concept to education, particularly in mathematics education, because, as as we have seen, it is part of a cultural movement. From this standpoint, we understand the simulation as:

> […] a specific moment in a learning situation, in which the subject is able to perceive and manipulate parameters, or invariant aspects involved directly in the development of concepts and knowledge in question. [...] In the case of mathematics education, for example, where situations involving tests and statements of theorems are valued, even if the simulation is not sufficient to form this type of argument, it develops intuition and prepares the student to assimilate broader levels of generality (Pais, 2008, p. 152, our translation).

Thus, according to Pais (2008), the nature of the knowledge that a simulation provides belongs to the application of rationalism, where basic aspects of knowledge change from a static configuration to one that is more dynamic and authentic. This is neither theoretical nor experimental but something that moves between these two poles. Care must be taken not to favor either side. Strive for balance even thought it is a complex and slippery goal because *to simulate is to interact*. The exercise of interaction is at stake in the exercise of simulation (Pais, 2008).

We see two types of interaction and simulation in these productions:

1. The first arises from interaction to produce themes using simulation – Synthesis Modeling.
2. The other arises from themes to use simulation in mathematics education – Synthesis Modeling.

From this perspective, we understand that the productions presented by students of the teacher certification course in mathematics are located in three sets of interwoven theoretical and experimental knowledge (FIG 06).

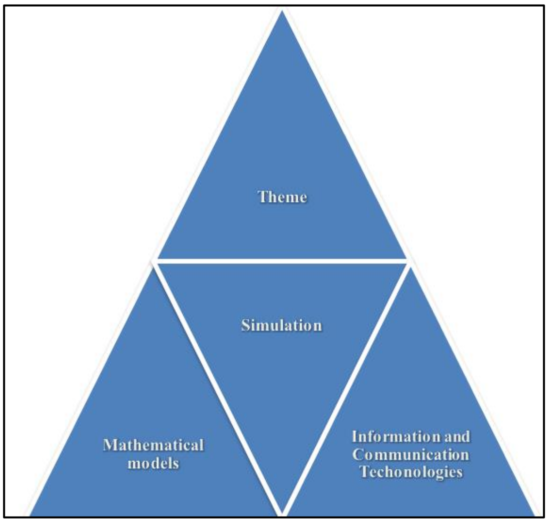

FIGURE 06 – Three areas comprising digital content production in mathematics.
Source: Same author, 2012.

In an experimental context, “Theme” is the transition from written language to mathmatical language. The “Mathematical Model” takes the mathematical language and translates the experiment into two distinct viewpoints: computer and human. Finally, “Technology” is created to explain the phenomenon of the experiment. Movement between these three areas (theme, mathematical model and ICT) is based on decisions, understanding variables and learning previously unimagined perspectives. In other words, simulation between themes, mathematical models and ICT is the act of choosing “paths” in mathematical knowledge.

Final Considerations

As new ways of expressing the human condition are created, the group of people who can find their unique place in the world expands (Kelly, 2010). Teacher’s training in a digital context offers a unique opportunity to feed the various interactions between these areas.

The examples show a process that can help us understand that modeling is the essence of a learning object for teaching and learning mathematics. It also shows that a digital society demands new forms and solutions for mathematics. These new forms make it possible to change the look of mathematical modeling. In a digital culture, the concept of mathematical modeling is actually a simulation environment in which interaction is simulated in four dimensions[3]:

1. **Dialogical,** becaue results (Models) need to be criticised in mathmatical dialogue and socially.
2. **Diverse**, because there can be many mathematical approaches to the same problem and even with the same mathematical model, results depend on the technology used. For example, the same mathematical model processed by Calc[4] will give a diferent result than the same by MatLab. Thus, diversity strengthens Mathematical Modeling.
3. **Dated**, because what exists is already “old”. The best mathematical model is the one that is thrown out in favor of a new way to see the world in a diferent and better way.
4. **Dynamic**, because, “When you look at the world through photography, the view is static. I see what is shown in the photo at that instant. However, if you look at the world through a window, the view is dynamic and you actually see the changes that are occurring” (Javaroni, 2007, p. 28).

This enquiry on the authoring process of students pursuing mathematics teacher certification demonstrated the importance of understanding mathematical modeling as a research strategy: Dialogical, Diverse, Dated and Dynamic. We have also come to understand that simulation is one of the ways in which to work with mathematical modeling in the digital culture of a teacher.

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[3] The text is based on a talk given by Prof. Dr. João Frederico da Costa Azevedo Meyer, at a meeting at the Federal University of Uberlandia in March, 2010.
[4] A free open source spreadsheet similar to Excel.

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