The educational robotics and Arduino platform: constructionist learning strategies to the teaching of physics

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Abstract. Today, there is a shortage of professionals with skills and knowledge to prepare the workforce of the future. In the 21st century we live in a technological society where the access to information is at our fingertips. In this environment, it is essential to rethink our attitudes towards educating future professionals that can meet the challenges that lies ahead. The school has a fundamental role in forming individuals, but in most cases the teaching methods are archaic and does not meet the reality of the 21st century students. In particular, the teaching of physical sciences, one of the keystones for the development of engineering and technology need to be urgently updated. In Brazilian schools the subject is introduced as disconnected from technology and more importantly from society. To reverse this trend, we have introduced Robotics to stimulate future teachers to engage in learning physical science through hands-on experience with technology at the State University of Maringá, Brazil. Thus, the question that emerges is if the educational approach using robotics, following a constructivist assumption, does modify the attitudes of pre-service teachers and later influences their teaching practices. The main goal of this work is to evaluate the impact of this methodology in constructing teacher’s professional identity, their familiarity with technology, and the introduction of new practices in classroom. Twenty five pre-service physics teachers used Arduino open source platform and educational robotics to assemble and solve open problems in groups of 4 or 5. After a brief introduction to the technology, they were encouraged to find solutions to the problem on their own. The theoretical assumption behind the courses is Papert’s constructionism. During the courses data was collected using video and audio recording as well as semi-structured interviews. After the courses, students were asked to run workshops to other undergraduate students. Through the observation of students in the workshop as well as the accomplishments of a focal analysis group, we evaluate the results of the introduction of robotics in physics teaching. We can identify that to change the future teaching practices and achieve the construction of a strong teaching identity, it is necessary for the student to learn and experience during their initial training period a methodology that provides the necessary subsidies for the development of skills and knowledge related to their teaching. In this way, Educational Robotics methodologically supported by constructionism, favors the reflection and a possible change of practices of future physics teachers, reaching the construction of the professional identity of the teacher.

1. Introduction
The current model of society, which is based on information and communication technologies, indicates the need for professionals who have multiple capacities to act, mainly having the competence to understand the set of information that surrounds and based on these concrete actions. The time of change in this society is in many cases represented by a very short interval when compared to the social structures of past centuries or decades.

And the information and communication technologies (ICT) available in this society are strongly linked to the technological applications of the scientific discoveries made at the beginning of the last century. Pierre Lévy [1], in his books "Cibercultura" and "The technologies of the intelligence", presents as transforming agent in the current society the use of the techniques. The author proposes these as a plurality of meanings with direct implications in the daily activities of society. Still, in the view of the author, there is a greater importance in the technique of communication, involving the transmissions and the treatment of the received messages. Lévy draws attention to the following point, to consider the computer only as an additional instrument to produce texts, sounds or images on fixed support (paper, film, magnetic tape) is to deny its proper cultural fecundity, that is, the appearance of new genres related to interactivity. The computer is, therefore, above all an operator of information enhancement.

The logic of the propagation of the media has a great impact of influence also in the economy. The mainstream media perceived this growing market, in which no social distinction is made and invests more and more in this sector. He believes that "in the information age, the most important thing is not the control of the means of production, but the control of the media" [2]. This power of information technology is installed in various media, such as social networks, television, radio, the Internet among others, promoting influences from the most diverse, from cultural, attitudes and even personal values.

Reflecting on the role of the school in this context, we identified the importance of knowledge and skills related to Science and Technology for the development of this society. At the World Conference on Science for the Twenty-first Century, developed by UNESCO in Budapest in 1999, it was already aimed at enabling countries to be in a satisfactory condition for the needs of their population, should have as strategies the development of Science and Technology, as well as in the schools should develop skills, competencies and scientific and technological knowledge.

In our society the formative role of the school has a particularized space, in which it can not be understood as independent of social phenomena and events. However, what is observed in times, is the distance of the school practices and the expected attitudes in the social reality. The difficulties in change are varied, lack of structure in schools, numerous classrooms, dependence on public policies that do not prioritize educational sectors, teachers' lack of preparation for new technologies and new methodologies are factors that undermine the educational system.

In this sense, worrying about the initial training of our teachers is extremely important. At present, teaching has undergone situations that increasingly weaken it, such as the valorization of the baccalaureate and the devaluation of the degree and the division between research and teaching [3]. Thus,

*educational change depends on teachers and their training. It also depends on the transformation of pedagogical practices in the classroom. But today, no innovation can move away from a change in the level of school organizations and their functioning. Therefore, to speak of teacher training is to speak of an educational investment of school projects.* [4].

Faced with this perspective the formation of teachers in Physics follows the same problem, because on the one hand we have a curricular component that favors learning and the use of technologies, on the other hand we have inflexible curricula, which do not methodologically favor the construction and formation with respect to scientific and technological literacy and that value the abstraction and mathematization of physics [5].

The aim of this research is to contribute to the work in this area by having as its central objective to evaluate the contribution of educational robotics through the use of the Arduino platform and supported methodologically by constructionism, in the modification of the teaching activity of students of the initial training of the course Physics as well as their professional identity. For this purpose, we characterize, through the analysis of the practices that involve educational robotics, the students'
attitudes in the classroom when they are submitted methodologically to the constructionism in the teaching and learning processes and thus, to identify if these attitudes influence and modify the teaching practice of these students.

These objectives allowed us to discuss the possibilities offered by constructionism, according to Papert, in the conduction of pedagogical practices that use as educational resource to educational robotics.

2. Methodology

As we mentioned, we intend to understand the construction of the teacher identity in the initial formation and the possible influences in its future teaching practice, in the light of the constructionism. Therefore, 25 students of the Physics course of the State University of Maringá were invited to participate in this research, belonging to the Physics course. The research was submitted to the Research Ethics Committee (CEP) of the State University of Maringá (UEM), and was approved by the opinion of number 2029.818, and a free and informed consent form was given to each student. One of the investigated signed and the researcher as well. As it is a qualitative analysis of the teaching practice of these students of the Physics course, our investigations would require the moment when they would be developing the methodological skills of the constructionism in the classroom, with their respective students. Thus, we elaborated a workshop of Educational Robotics that was ministered by the scholars in the XXV Week of Physics of the UEM. The workshop had the participation of 8 students belonging to the Engineering and Physics courses of the same teaching institution. For data collection, we used as instruments individual and group semi-structured interviews (at the beginning of activities and at the end of the activities), questionnaires and video recording during the execution of all classes.

The activities described in this research followed the theoretical and methodological assumptions of constructionism [6;7], in which the teacher's attitudes should be based on promoting situations that can motivate the students to identify with the knowledge and perceive the necessity of this in actions taken in the classroom, thus favoring the construction of knowledge. The student, in the constructionist approach, leaves his zone of comfort and passivity, usually seen in the classroom, and becomes an active agent in the teaching and learning processes, acting on the object and relating to other colleagues and teacher. For methodological development, we divided our actions into three phases:

**Phase 1: Deconstructing ideas**

We point our here a moment of deconstruction, since much of the teacher's identity is built throughout his student life. In this way, innumerable traditional attitudes were already realized for the subjects involved. To deconstruct the ideals would be to provide reflective moments of the teaching practice, and to lead them to rethink how one learns. At this stage we deal with constructionism X instructionalism and the history of technological development.

**Phase 2: Student Constructionists**

From our studies related to the construction of the teaching identity, we understand that this is built throughout the history of each individual, so this phase received this title. That is, how would we simply evaluate the teaching practice of our students from the point of view of constructionism, if they have until then received much education in the traditional process. Thus, this is the longest phase of our project, because we allow situations for our students to perceive the constructionist educational environment and thus to really understand this methodological practice. In this phase we approach the arduino workshop and Robotics workshop. Table 1 below presents the activities developed with Arduino in the Arduino and Robotics workshops.

**Table 1. Activities of Arduino and Robotics workshops - Source: Own authorship.**

| Arduino Office | Robotics Office |
Sensors and use of digital and analog ports as inputs

Sensors to monitor the ambient temperature (LM35), lighting (LDR), position of angles (potentiometer).

Robotic arm with servomotors

For the assembly it was used the servomotors controlled by the Arduino.

Actuators and use of digital and analog ports as outputs

Control leds (one color, RGB), sound emitters (Buzzer), using “motor shield” to drive motors, motors as servomotors, DC motors and step motors. Robot controlled by remote IR

Tracker Robot

For the assembly DC motors were used with LDR as track sensor and LEDs to illuminate.

Robot controlled by remote IR

For the assembly DC motors with IR sensor were used to control the movements of the robot.

Phase 3: The teacher-building action

This is the last phase of our activities. At that moment we evaluated the actions as students of the Academic Week of our students of the Physics course. We allowed all the preparation of the Workshop to be carried out by them, from the choice and production of the materials, to the planning and application of the classes. They taught a robotic workshop with the Arduino platform, working on the programming aspects of Arduino's IDE, and later building robotic devices as a robot controlled by remote IR, using these learned skills. We present in table 2, a summary of the activities developed in our research, including the workload for the realization and the objectives to be achieved in each phase. The picture shows different colors, highlighting what was done in each phase.

Table 2. Summary of activities carried out in our research - Source: Own authorship.

| Activity                        | Workload | Participants                                      | Objective                                                                 |
|--------------------------------|----------|--------------------------------------------------|--------------------------------------------------------------------------|
| Construction X Instruction     | 9 hours  | Students of the Physics course                   | - Reflect on the methodological differences of these two currents         |
| History of technological       | 18 hours | Students of the Physics course                   | - Promote reflections on the concept of technology and especially its social and educational impacts |
| development                    |          |                                                  |                                                                          |
| Arduino Office                 | 42 hours | Students of the Physics course                   | - Develop knowledge and skills in the use of electronic devices, especially the Arduino Platform
- To promote the study of programming in the Arduino IDE |
| Robotics Office                | 60 hours | Students of the Physics course                   | - Develop skills in the use of electronic devices in robots
- Carry out practical Robotics activities based on Methodology in Constructionism |
| Academic Week Workshop         | 24 hours | Students of the Physics course + students of the academic week | - Analyze the development of teaching practice, based on the methodological construction of Constructionism |
| Academic Week Evaluation       | 3 hours  | Students of the Physics course                   | - To develop and analyze the reflection of scholarship students in relation to the teaching practice that they |
3. Analysis of results
For the development of the analysis we elaborated the corpus of the text with constituent elements of the interviews (initial and final) with the students of the Physics course, the questionnaires and the practices carried out during the project workshops, as well as the students of the Physics course. We also used the questionnaires (initial and final) with the students participating in the Academic Week. And to triangulate our data, we made use of the analysis of the Curricular Pedagogical Project (PPC) of the Physics course of the State University of Maringá. For this, we perform the transcriptions of the speeches of the social actors involved.

We also call attention to the textual structure in the following aspect, the excerpts of narratives featured at the end of the sentence an index, such as; (E1, E2, E3, E4 ...) to register students of the Physics course and (A1, A2, A3, A4, ...) to identify the students participating in the Academic Week. We group the speeches of the subjects of the research, and we ratify this theme in the construction of the identity, because we reflect on the subject that can model and construct their teaching identity, in an individual and collective process. For Marcelo Garcia [8] "The construction of the professional identity begins during the period of student in the schools, but consolidates itself in the initial formation and continues throughout his professional practice". Experiencing and experiencing teaching practices in the student position is fundamental to the process of recognition and incorporation into identity. Nóvoa points out,

*Training should stimulate a critical-reflective perspective, which provides teachers with the means of autonomous thinking and facilitates the dynamics of participatory self-training. Being in training implies a personal investment, a free and creative work on the paths and the own projects, with a view to the construction of an identity, which is also a professional identity* [4].

To think about the change in the future teaching practices of the undergraduate, without actually experiencing the entire formative process would be to remain superficial. This generation is familiar with the traditional educational practices in which they were part of their formative process. Thus, it is necessary to allow situations of student experience of new methodologies that provide spaces of personal and professional interactions, allowing the appropriation of new knowledge of teaching practice. In this way, we present four themes analyzed in our research related to the subject.

*Educational Robotics - a Tool for Teaching Physics*

The knowledge of the concepts that involve Physics is necessary for the understanding of the events on the part of the subjects. Santos and Menezes [9] point to educational robotics as a facilitating device for Physics Teaching, in the research the authors propose the inclusion for students who are starting their studies with the curricular component Physics and present important data dialoguing with this idea and argue for a breakthrough in the student learning with respect to physical concepts.

At first, it is believed in the motivating role of educational robotics, with its playful character can at the beginning captivate the students and instigate their curiosity regarding the subject, "a lot of people like robots, and I think I feel very encouraged to participate in a course like this, with very nice classes and that draws attention to something different "(E17). This excerpt, "something different," denotes the student's quest for activities that may come out of the traditional, in which they are accustomed. We record another speech from another student who presents us with the same context,

*When I was in high school and fundamentally, the classes were only theoretical, I never saw anything in practice. When I arrived at the university and went to a laboratory and could actually do something with my hands I was delighted. So I believe in it, that Robotics brings about that liberating sense of being able to see and do things in practice.* (E7)

One of the factors that discourage our students in the learning process, especially in the sciences, are methods that value memorization rather than experimentation as a complement, leading to some misconceptions and false interpretations [10;11]. Thus, it is necessary and urgent to rethink pedagogical practices and the insertion of technological tools such as educational robotics, since

*in the educational scenario, especially in Physics teaching, it can be thought of as a set of dynamic tools, capable of positively influencing the learning process, favoring the development*
of skills such as solving logical and mathematical problems, creativity and critical reasoning, besides to promote scientific literacy [12].

The Physical curriculum component establishes a close relationship with technological phenomena, since it is from their concepts that the development of technology happens. National Curricular Parameters point out that physics should promote a contextualized knowledge of the activities allowing students to construct their conceptions of each content, so "Physics deals a lot with technology, so I believe, that robotics provides a greater insight into the applications of Physics "(E11). Thus, the attitudes and the role of each one involved in the teaching and learning process become clear, being all agents in this process. Thus, "educational robotics ends with the idea that the student is only a receiver" (E2). In this way, we were able to identify in the students' speeches this positive expectation regarding robotics due to its motivating character. In the last decades, robotics has been demystified, because it is closer to individuals, overcoming the barriers of science fiction, so "Robotics itself is already an issue that matters, I grew up watching drawings with robots, and then you can put the robotics to explain concepts and contents of physics must be amazing and fantastic "(E10).

In this motivating context that the educational robotics can cause, we raise a second moment, in which we believe in the facilitating character of the robotics as to changes in the teaching practice. When engaging in teaching through educational robotics one must take into account the great importance of the methodology adopted

In high school I had robotics classes, but they were just like that, let's open the book on such page, so my experience was not good was not anything cool. Now I am very curious and excited to see the use of robotics following the methodology of constructionism (E18).

I really like Robotics because I always had it in my high school [...] it's very interesting to have contact with things before and then to be curious about them (E24).

Reflecting on the excerpts from the students above, we perceive two different situations presented by them. For the E18 student, the experience lived during his passage through Elementary and Middle School, in which educational robotics was part of his education, is not considered as positive and useful because methodological interventions do not favor the construction of knowledge and the discovery of the new, the student makes clear the instructional character of the classes and presents a willingness to know a new methodology when referring to constructionism. As Beauchamp and Thomas [13] present, experiential knowledge is part of the construction of the students' professional identity, so their experiences collected during the student life interfere in the conceptions of the teaching performance. Already in another speech, student E24 reports the positive experience experienced with educational robotics in the school where he studied. For the student contact with the concrete before the construction of the abstract knowledge was fundamental in the learning process. Therefore, we perceive that even in different ways the experiences lived by the students influence the constitution of the conception of the teaching activity. The teacher must be prepared for diversity and the pluralities of the profession, and the intellectual, emotional, social, moral and aesthetic development must be in preparation [14, 15].

As for the inclusion of educational robotics in the education system, Eguchi [16] presents the need to include it in the secondary and fundamental school curriculum, since the author reports that for decades the importance of technology in education has been discussed, yet it is very far from this really effective insertion to happen.

The Constructivist Practices
An important factor in the discussion regarding the use of technological devices refers to the techniques used by the students in the execution of the proposed tasks. We privilege with the methodological support of constructionism the freedom of each student in the development of attitudes regarding the decisions to be made.

When pedagogical work uses the use of the Internet and technological devices as a resource, the tendency is not to impose the knowledge pertinent to these subjects to its student, but it privileges the questioning, the discussions and the reflections on new ways for the discovery and construction of that particular knowledge. In this way, the learner previously develops unprivileged skills in traditional
teaching, such as: mental flexibility, cooperative learning, adaptation to different rhythms of comprehension, increased creativity, autonomy disposition.

In order to identify the constructivist practices achieved by students, we adapted and based on three main characteristics of a constructionist environment presented by Rezende [17].

(a) Pedagogical mediation - For the author, it is a process that must have a balance between the articulations of the teacher's actions and the student's awareness as an active subject in the construction of knowledge. As we mentioned in the previous category, in the beginning of the activities, the students presented difficulties in the decision-making before the proposed activities. However, we observe throughout the workshops the change in this aspect as we identified in the following statements:

Teacher does not talk like it has to be done, I'm already on the way and I think it's right (E10).
I will not have problems in developing this semaphore, just change the time here in the blinking LED programming (E5).
Our teacher, I was the student who most complained when you did not say what should be done, now I get angry when someone comes here and talks before I try (E2).

We emphasize the statements of students E10 and E5, because in the previous category, they presented difficulties of autonomy in the process of identifying errors and the construction of knowledge to develop the suggested tasks.

(b) Activities in student control - The author argues that the tasks assigned to students should be free to execute. This freedom provides the autonomy of the student and stimulates the development of activities. In these aspects we do not identify problems, because the use of the Arduino platform has exactly these characteristics in its applications.

At first, we thought about creating a robot that did a lot of things, to be very good, but when we started thinking about programming, we saw that we had to rethink our robot (E3).
When you begin to think about what you are going to do, the ideas are numerous, but when you begin to put it into practice you have to rethink a lot of things. Especially in programming, the more difficult the engine gets (E11).

In the speech of the two students, we can identify the relationship of knowledge construction, with the Arduino IDE and the robots that are being developed. The reports present the three moments of the cycle of elements of constructionism, defined by Valente [7], the execution, the reflection and the debugging. These elements are fundamental, since they depend on the actions of the students. When they mention what they intend to develop and put into practice, we have the execution. At the moment that they perceive the difficulties, mainly with the programming we have the reflection and when they define other strategies it presents the debugging.

(c) Interactions between agents - An important characteristic of constructionism are the relationships that happen between teacher-student and student-student. For the author, these interactions should be surrounded by situations of trust, respect, freedom to express themselves and collaboration. In this situation we see a great advance in the process presented by the students. We worked with the robotics project in groups, so in all classes we asked for the formation of "islands" (grouped portfolios). In this way all students interacted with the object equally. The groups also alternated as the activity changed, to really happen the exchange of experiences.

Group work is always difficult, because each one has a different idea, but we have managed to overcome this, we have been testing everyone's ideas until we see the best solution (E23).
At first, I thought I would not collaborate with virtually anything from my group, but all of a sudden I was researching and helping get our project better (E12).

Another interesting point was in the beginning, some students were limited in not using materials such as soldering iron, micro grinding and drilling, but gradually one student was giving confidence to the other and in the end we found that everyone experienced this experience. The following figures illustrate our arguments as to how the activities happened.
The Error Problem

In our culture the act of making mistakes implies in several moments the understanding of failure or incompetence. The mistake confuses individuals by removing reason and giving rise to emotions, where we find varied feelings such as: "shame, I do not like people to realize that I made a mistake (E4) or" I feel incapacitated, it seems I had to know how to do it " (E18), but there are also people who are natural because "I read well with the mistake, I think it's funny that you make a mistake, you make it easy for me, I did not realize it, just like proof you're going to do it later and you do not believe what you missed "(E24). In this dispute between reason and emotions Damasio, in his book "The Error of Descartes" presents,

Knowing the relevance of emotions in the processes of reasoning does not mean that reason is less important than emotions, that it should be relegated to the background or should be less cultivated. On the contrary, when we look at the broad function of emotions, it is possible to highlight their positive effects and reduce their negative potential [18].

When analyzing the error from the viewpoint of reason, we can see that in order to get it right several times it is necessary to err and reflect on the situation. In construction, Papert [6] argues that the concept of error is only an unexpected act, and it should be studied and brought to the discussion to construct new conceptual elements for another solution. Our educational system often reinforces the idea of error as something related to disability. This is especially true in evaluation processes, where students are not led to reflect on their mistakes in activities, only know if they are approved or disapproved.

We identified in our students a certain concern about the error, the fact of breaking the equipment or damaging, "I'm afraid to burn an Arduino" (E21), or "Is it dangerous to ruin a transistor? "(E19). We present the limits of each device that would be used, and we encourage the use for the knowledge of the materials. We observe in the following statements,

Ah the fear of making mistakes is natural to the human being, but here I did not see it as a mistake but as a new attempt (E9).
At first, I thought that the equipment would not be released for us to use that way, but when I saw that the teacher relies on us it is because it should work (E17).

We emphasize that as the students acquired more autonomy, the way of dealing with the error was transformed. And this situation is directly related to the direct contact with the other, since they began to observe that even the students considered more knowledgeable of the subject also was mistaken in some moments. In this way, the ideas already formalized with respect to the error were broken, and the space was growing for new discoveries.

Educational Robotics and Teaching Practice

Reflecting on the teaching practice leads us to a pertinent and complex concern at the same time, therefore, we question what competences, abilities and knowledge we must acquire to facilitate the process of teaching and learning nowadays. To rethink "the teaching work is not, or rather, should not be an isolated task, and no teacher should feel defeated by a set of knowledges that, certainly, surpass the possibilities of a human being"[19]. In this context, educational robotics presents a possibility to teach using technological resources in a playful way. We present below the students' reports when questioned about the use of robotics.

Bringing an experiment into the classroom is cool, students like, but robotics is much more complete you bring all areas of physics into building just one robot and still you can tackle other disciplines too, such as Chemistry, Mathematics, Biology knows all of them. (E9)
One thing I discovered and changed my way of studying, was that you see in the graduation everything fragmented and in the robotics, not mechanical, one thing, another thermology, electricity another, robotics makes you understand the relationships of the areas. (E7)

We identified in the students' statements aspects presented by Papert [6], in which robotics being methodologically conducted by constructionism can overcome the barriers of playfulness and influence the construction of specific knowledge of each area, in the case of this study Physics.
In the course of the workshop, physics course students were free throughout the process, from the choice of activities to making decisions in the classroom. Actually they experienced each step and the construction of the robotic devices present moments of great interaction of the students of the course of physics and the academic week. Some speeches called attention to the possibility of incorporating robotics in the future teaching practice of these students, so "the certainty that I will use robotics in the classroom, especially the Arduino, because if it was easier for me to understand Physics for my students will also be" (E3), for the student (E6) “I did not think it could be so captivating to work with the robotics, the students did not even notice the hours pass, I already bought my Arduino and I will continue studying”. In this way, we understand that educational robotics can favor the learning process of Physics contents and mainly provide an environment of exchange of information together teachers and students.

4. Conclusion
The teaching of physics has gone through decades of discussions and reflections about content, methodologies, experimentation. The arguments are largely based on the difficulties presented by the students who have contact with this curricular component and who report a certain distance from it, due to the absence in the comprehension of its contents. A Science of nature like Physics, which has so many everyday situations experienced by the student, therefore, would have many possibilities to relate theoretical content with concrete phenomena.

We identified in our research the potential of educational robotics, as a methodological resource, in favor of a learning in which it is concerned with the cognitive structures of the student through their actions. For Papert [6], the construction of knowledge surpasses the difficulties, when the student is first led to objects of his interest, and from then on he discovers the concepts necessary for his execution. We observed after the interventions made that this expected change in the profile of the students was achieved, through the motivation added by the educational robotics. In this way, educational robotics is an important alternative as a pedagogical tool for physics teaching. It is an educational proposal that comes together with learning theories, such as constructionism, to facilitate the development of logical-mathematical intelligence, to value the construction of autonomy and creativity on the part of students, to favor interpersonal and intrapersonal relations and this collaborate with group work. Thus, educational robotics, allows the student to become an active subject in the learning process, and this phenomenon is fundamental in the treatment of Sciences.

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