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Graphic Programming Artefacts in the development of geometric skills

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Abstract. Computational thinking, critical thinking, problem solving, creativity and collaboration are just a few examples of a broad range of 21st century skills which are key to the education of students and active citizens of the future. Enhancing its development while mobilizing content, pedagogical and technological knowledge, is one of the main challenges of 21st century teacher practice. Having as background a pilot implementation of a study, centred on Mathematics, which aims to investigate the influence of collaborative programming activities on the development of the abilities to solve and formulate geometric problems, critical thinking, creativity and collaboration, in this article we intend to characterize the signs produced during the resolution of collaborative problems through graphic programming artefacts. The research methodology is qualitative with case study design. The data collection techniques are: participant observation, supported by field notes / logbook; questionnaire survey; documentary collection (audio-visual and photographic records and written documents produced by the students). The preliminary results point to the existence in the programming activity of a dependence between the signs of graphic programming artefact and the mathematical signs. When mathematical knowledge is not properly mobilized, programming projects them. Then, the opportunity arises to think critically, and other signs can emerge, such as the pivot signs in the mobilization/construction of knowledge.

Résumé. La pensée informatique, la pensée critique, la résolution de problèmes, la créativité et la collaboration ne sont que quelques exemples d'un large éventail de compétences du XXIe siècle, essentielles à l'éducation des étudiants et des citoyens actifs de demain. Améliorer son développement tout en mobilisant contenu, connaissances pédagogiques et technologiques, est l'un des principaux défis de la pratique pédagogique du XXIe siècle. Ayant pour toile de fond une implémentation pilote d'une étude centrée sur les mathématiques, qui a pour objectif d'examiner l'influence des activités de programmation collaborative sur le développement des capacités de résolution et de formulation de problèmes géométriques, de pensée critique, de créativité et de collaboration, nous nous proposons dans cet article: caractériser les signes produits lors de la résolution de problèmes de collaboration par des artefacts de programmation graphique. La méthodologie de recherche est qualitative avec un plan d'étude de cas. Les techniques de collecte de données sont les suivantes: observation participante, appuyée par des notes de terrain / journal de bord; questionnaire d'enquête; fonds documentaire (enregistrements audiovisuels et photographiques et documents écrits produits par les étudiants). Les résultats préliminaires mettent en évidence l'existence d'une dépendance dans l'activité de programmation entre les signes d'artefact de programmation graphique et les signes mathématiques. Lorsque les connaissances mathématiques ne sont pas correctement mobilisées, la programmation les projette. L'opportunité de penser de manière critique se présente alors et d'autres signes peuvent émerger, tels que les signes pivots de la mobilisation / construction du savoir.

1. Introduction

Technologies are present in our day to day, but how can ICT be used in teacher training to promote mathematics comprehension? The challenge is to guide future teachers and educators towards an appropriate use of ICT (concerning teaching/learning contexts).

In its position about “Strategic Use of Technology in Teaching and Learning Mathematics”, NCTM (2015) defends the need to carefully consider and design ways for students and teachers to use both digital and physical tools so that the full potential of technology is employed on enhancing “how students and educators learn, experience, communicate, and do mathematics” (p. 1), promoting a math learning experience which involves students in meaningful practices, engaging the development of skills such as critical thinking, collaboration, problem solving or creativity, in line with 21st century skills (WEF, 2015).

The TPACK theorical referential (Mishra & Koehler, 2006), which has its genesis on Shulman’s ideas, also states that teachers are expected to mobilize technological, pedagogical and content knowledge when developing a carefully defined curriculum.

Nowadays, we can purchase a set of programable devices (such as lego wedo 2.0; the Parrot minidrone; Sphero 2.0; a robot mouse; and the robot Doc) which can be connected to tablets, mobile phones and computers. Their programming may support the formulation and/or resolution of creative and challenging tasks (which can also be collaborative), combining fun with learning.

In this article, we focused on the analysis of the results of one of the tasks implemented in a pilot study, which intends to analyse the influence of programming activities in collaborative, challenging and fun contexts, in the development of the skills required to create and solve geometrical problems, critical thinking, creativity and collaboration by future teachers and educators. So, with The Postman's Task, which uses Sphero 2.0, the mini drone and graphic programming software (Scratch and Tynker), we tried to understand, under the Semiotic Mediation Theory (TMS), which signs are produced in the various phases of the resolution of the task and the difficulties that arise during it.

2. Artefacts and their Semiotic Potential

The construction and use of artefacts are intrinsically linked to human activity. In addition to contributions to a more practical level, they can intervene at a cognitive level, challenging new ways of thinking and acting (Norman, 1993).

According to Bussi and Mariotti "any representation is supported by an artifact" (2008, p. 748). It is thus fundamental to understand the role of artefacts in the creation of representations and how they act on cognition in the emergence of new abstractions.

According to the same authors (2008), a double semiotic link is established when we analyse the semiotic potential of an artefact:

> on the one hand, personal meanings are related to the use of the artifact, in particular in relation to the aim of accomplishing the task; on the other hand, mathematical meanings may be related to the artifact and its use. (Bussi & Mariotti, 2008, p. 754)

The TMS (Bussi & Mariotti, 2008) identifies 3 main categories of signs: artefact signs, pivot signs and mathematical signs (figure 1).

The artefact signs (Bussi & Mariotti, 2008) are those that emerge from the use of the artefact to carry out the task, those that trigger the construction of mathematical knowledge. Although the meanings of the artefact signs are personal, the task may lead to the need for negotiation of shared meanings.

The mathematical signs refer to the mathematical context, "these signs are part of the cultural heritage and constitute the goal of the semiotic mediation process orchestrated by the teacher" (Bussi & Mariotti, 2008, p. 757).

The pivot signs (Bussi & Mariotti, 2008) are a symbolical representation of the hinge which potency the first detachment of the artefact, promoting the passage from the context of the artefact to the mathematical context, but maintaining the connection to the artefact.

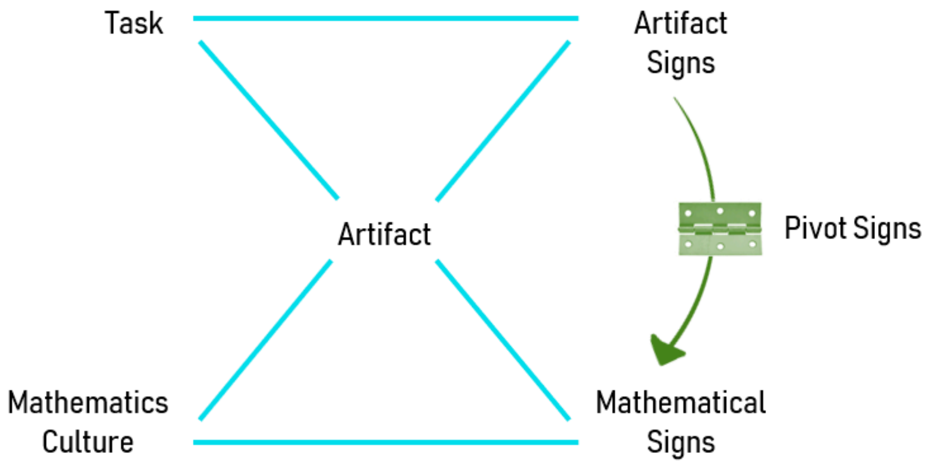

Figure 1: Artefacts and signs, adapted from Bussi and Mariotti (2008, p. 757)

3. Methodology

The research methodology is of a qualitative nature with a case study *design*, involving two 3rd year classes of the Basic Education course at Viana do Castelo Higher Education School.

The Postman Task, presented in Figure 2, was solved by 36 of the 40 students, organized in 13 groups (eight groups of three students, four groups of two students and a group of four students).

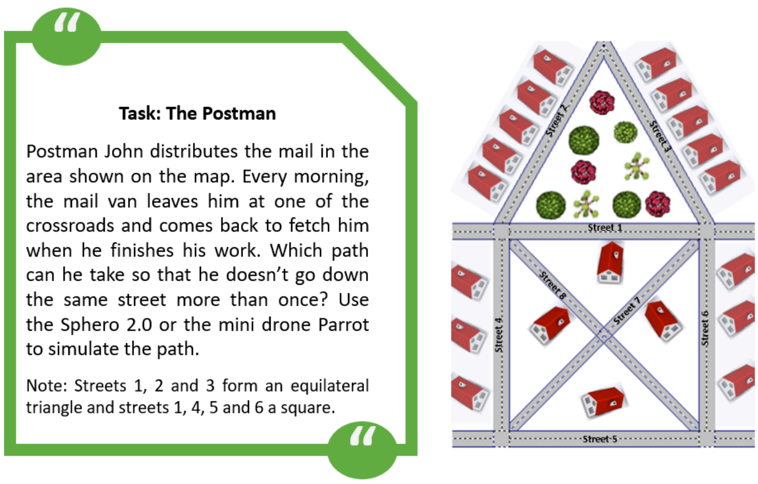

Figure 2: The Postman Task

Each student was asked to solve the problem individually. After finding the solution they should

discuss with their group which strategy should they use to program the mini drone Parrot or Sphero 2.0. They began by using Scratch to model the way to go (since we don't have drones/Spheros for all groups). When their commands were inserted in Scratch, they submitted them in the Moodle platform and only then they could test them. After the test, they corrected the errors and adapted the programming to the Tynker software to activate the drone or Sphero (these artefacts are programmed by time, whereas in Scratch the actors are programmed in steps).
This task is one of four tasks implemented. Students, using graphical or tangible programming of 2.0 devices, such as robots and drones, mediated by tablets and computers, recorded the strategies used during the resolution through video and photography, supporting a collaborative reflection of the resolution of each problem. The final work is a report which contains the reflections of the solved problems and a didactic sequence.
The data collection techniques were: participant observation, supported by field notes / logbook; questionnaire survey; documentary collection - audio-visual and photographic records and written or digital documents produced by students.
The analysis focused on the resolution of the postman's task and part of the results of the questionnaire, contemplating the following categories of analysis: difficulties and type of signs produced.

4. Results

All students were able to identify a path that respected the conditions of the problem.
Most groups elaborated initial schemes such as those presented on figure 3, which show no mathematical signs like the Pythagorean Theorem or a relationship between angles.

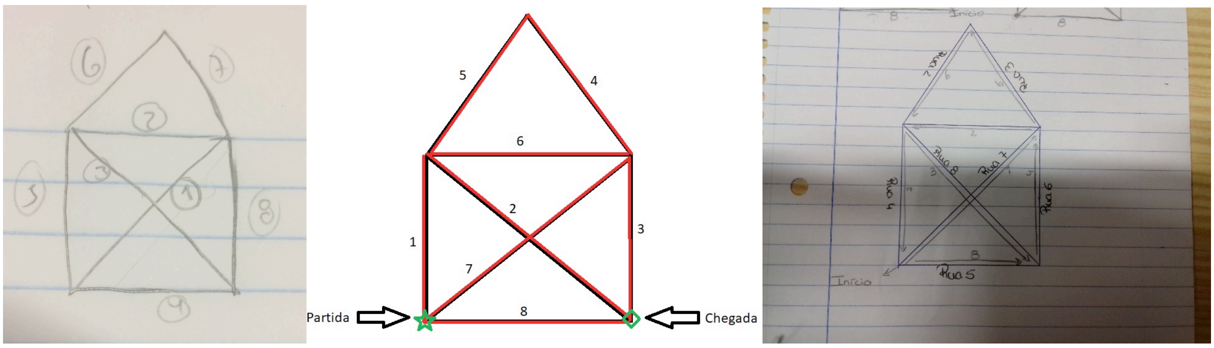

Figure 3: Examples of solutions presented by some groups

However, other groups elaborated schemes which show the emergence of other pivot and mathematical signs. In figure 4, we can see that the group indicated the amplitude and the direction in which the angles should rotate, as well as the number of steps required to go through each street. In addition, it included the calculation of the Pythagorean Theorem.
In figure 5, the group used drawings to relate the amplitude between the angles. In the upper right corner of this figure we can observe the enlargement of only part of the map, in which the group shows they recognize the relations between complementary angles. Still in this figure and focusing on the map, the group showed they knew the concept of supplementary angles.
Figure 6 has the schematic with the most information. We can see that they calculated the hypotenuse and indicated the amplitude of all angles presenting, as on the previous example, the

drawing of lines which show the relation of supplementary angles.

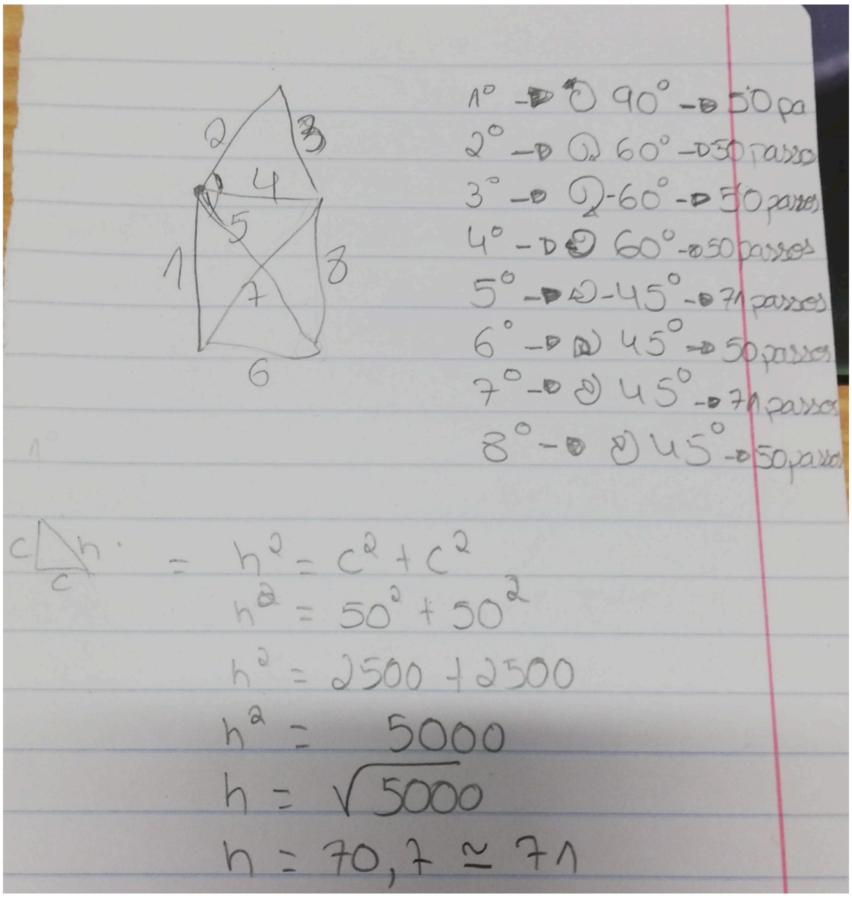

Figure 4: Example of a scheme that indicates the amplitude and the direction in which the angles should rotate and the hypotenuse calculation

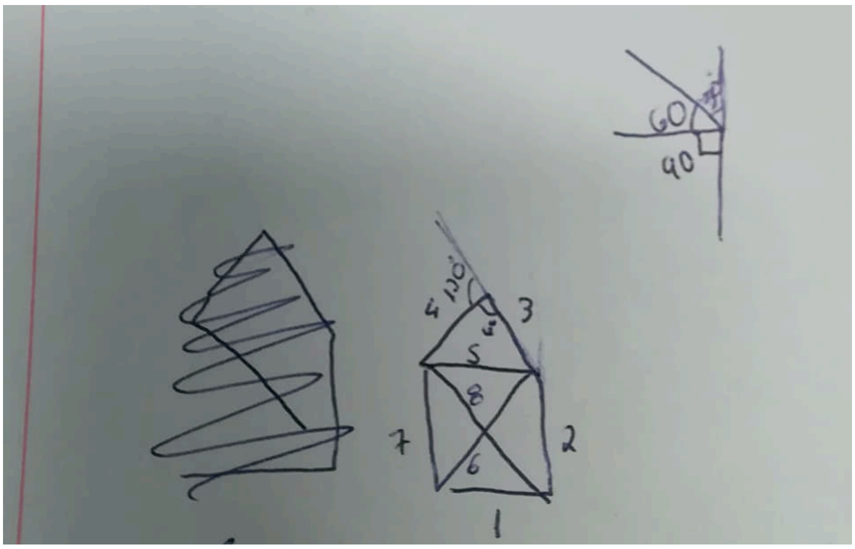

Figure 5: Example of a scheme with evidence of relations between angles

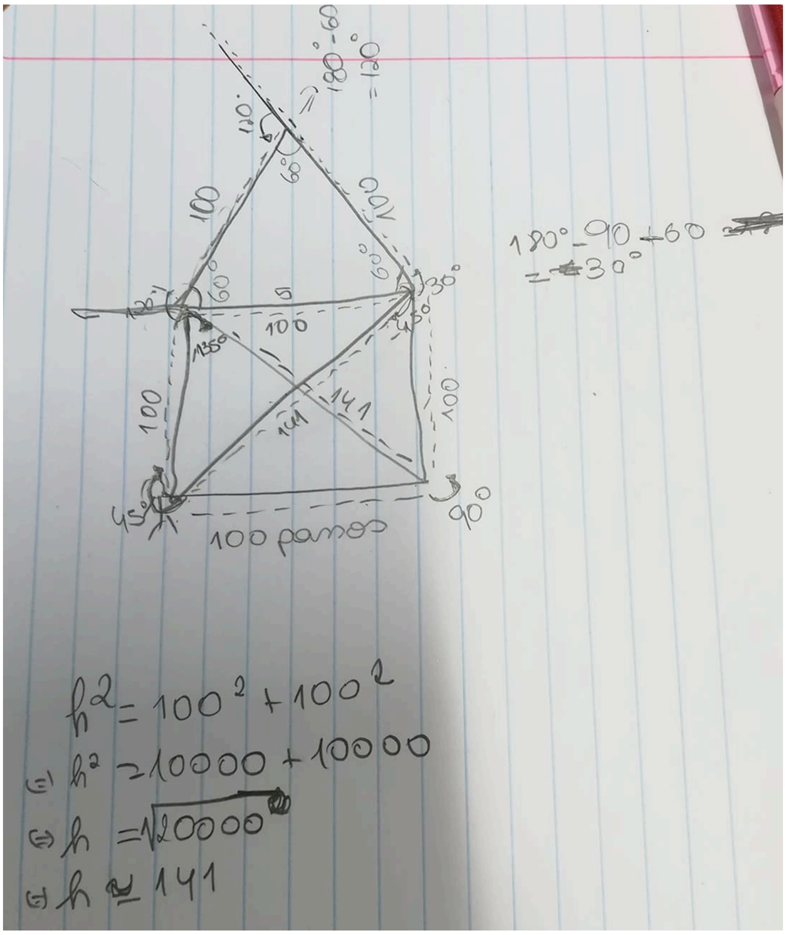

Figure 6: Example of a scheme with evidence of relations between angles and hypotenuse calculation

When students collaboratively programmed the path in Scratch, the results were not expected for 11 of the 13 groups, as shown on Figure 7 (Group G5 did not submit the files but, in the reflection, they admitted they didn't achieve it). The length of streets 7 and 8 had to be calculated using the Pythagorean Theorem, but only six of the groups realized they had to mobilize this knowledge (G2, G5, G7, G9, G10 and G11). Another common mistake concerned the triangle formed using streets 1, 2 and 3. This is an equilateral triangle, but 4 groups considered that the angle formed by streets 2 and 3 was rectangle (G1, G8, G10 and G13), as shown on the dialogue with group G8:

Teacher: Does this triangle have a 90º angle?
G8: No, supposedly it has 60º.
Teacher: Why?
G8: Because all sides are the same.
Teacher: But you said it was 90º.
G8: Yeah…
Teacher: Did you forget? Didn't you read the statement carefully?
G8: We didn't think about it. We only worried about rotating an angle.

In addition, as shown on figure 7, most groups miscalculated some angles.

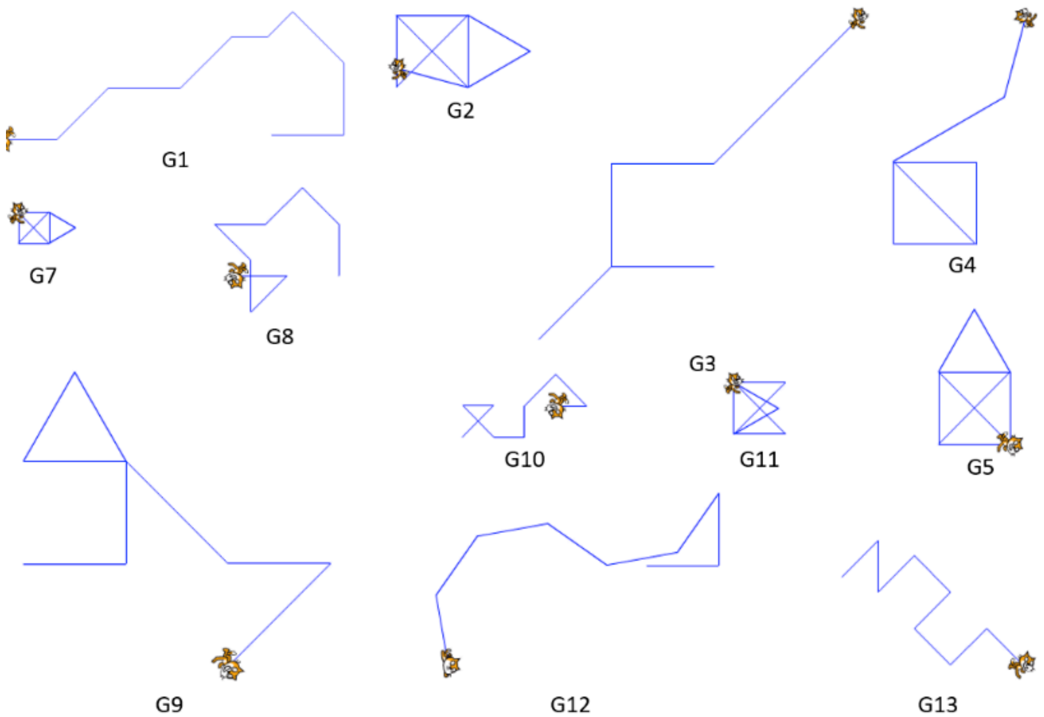

Figure 7: Results of the students first attempt to graphically program the postman's path

However, after testing their programming, the groups worked collaboratively to correct the mistakes made. The majority showed autonomy, although some of the groups requested help from the teacher.
As they finished, they adapted the programming to the Tynker software installed on the tablet. For this, they began by testing the time in seconds that each of the artefacts took to travel a certain distance, as can be observed in the Figure 8.

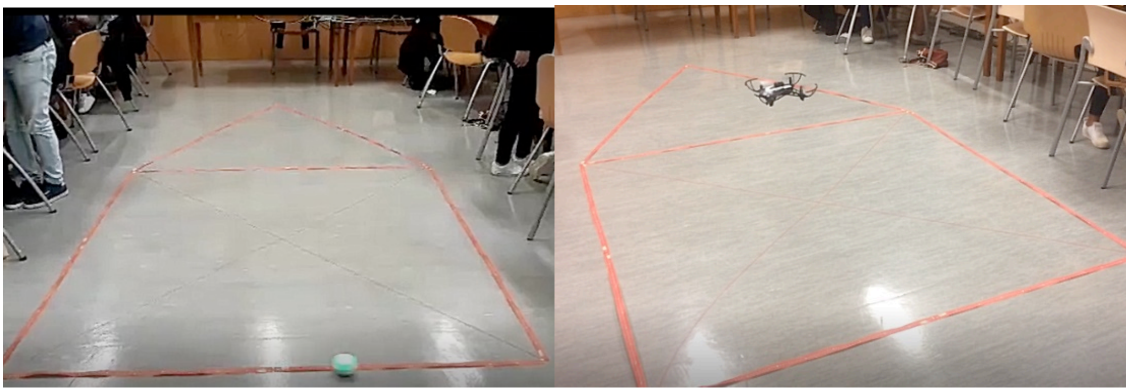

Figure 8: simulation of the postman's path which was to be replicated using the Sphero 2.0 and the mini drone

5. Final reflection

The observed interactions led to the coexistence of artefact signs and mathematical signs mediated by pivot signs. The artefact signs are those that arise from the use of the artefact and in the case of Scratch or Tynker are associated with the construction of the puzzle of commands that originates the graphic programming, but the graphic programming requires the mobilization of mathematical signs. As noted above, most students made a few mistakes when they made the first attempt, but this allowed them to use the image produced by the software to understand the mistakes they had made. Some resorted to pivot signs and went from the map artefact to the digital artefact, as well as other which went the other way around going from the digital artefact to the map artefact. For instance, some used hand gestures both on the map and on the computer/tablet screen, stating the angle on which to turn; others pretended to be the postman and simulated his trajectories on the map drawn on the classroom floor. In any case, they correctly mobilized the fundamental mathematical signs to solve the problem.

In this sense, the scheme proposed by Bussi and Mariotti (2008, p. 757) requires an adaptation. This scheme suggests that we move from artifact signs to mathematical signs through pivot signs. However, in this study, it is observed that the relationship between signs is more dynamic, not just unilateral. Since artifact signs emerge implying the immediate mobilization of mathematical signs, that is, the programming of the path involves using mathematical signs, as we have seen, mediated by pivot signs (gestures, drawings, dramatizations). After the programming was tested, we can see that the concepts may not have been correctly mobilized or not mobilized at all (for example, the Pythagorean Theorem). Based on the produced graphical result, we once again resort to pivot signs reflecting on the mistakes made, and thus new mathematical signs emerge. We can move from artifact signs to mathematical signs and vice versa until we solve the problem, hence in Figure 9 the scheme was adapted by placing the arrows in both directions.

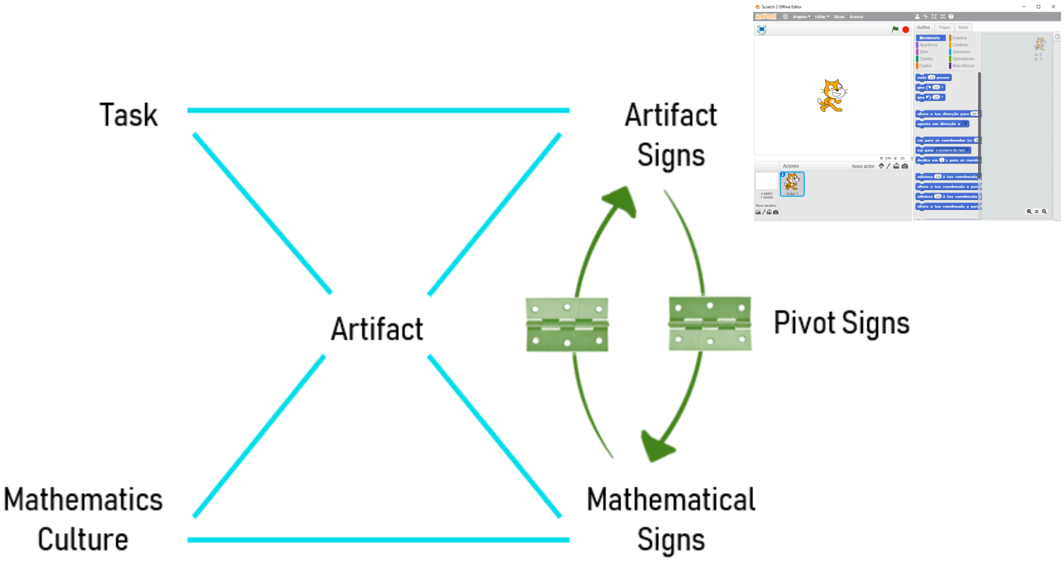

Figure 9: Artifacts and signs in programming tasks

This experience mobilized geometric knowledge in a way that had meaning for the students, promoting the development of their critical thinking and collaborative work. This meets Lopes, Silva, Dominguez and Nascimento (2019) when they defend that it is imperative to develop these skills, contributing to the students technical and professional development. For instance, in the final questionnaire most students agreed or completely agreed with the statement "I was wondering about the path I was using (knowledge and strategies).", suggesting they mobilized critical thinking during task resolution. In addition, they stressed the importance of collaborative work, emphasizing "sharing of ideas", "overcoming obstacles", "sharing strategies", "learning with colleagues", "fostering persistence", "working in a relaxed way".

6. References

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