Nurturing self-regulation by mathematical inquiry in a one-to-one TEL environment

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Abstract: We design and evaluate a curriculum-based mathematical learning activity involving secondary students' geometrical constructions, mathematical modeling and algebraic validation of hypotheses based on hands-on explorations with the interactive geometry application GeoGebra available on individual laptops. We argue that guided inquiries in a technology-enhanced learning environment that invites blending of interactive technologies and traditional resources may be an efficient means for developing self-regulatory skills.

Keywords: Self-regulation, inquiry-based learning, TEL, mathematics, geometry, algebra.

1. Introduction

We have designed and implemented a mathematical learning activity addressing coordinate geometry and specifically the distance formula. The activity involves guided inquiries and is intended for use in upper secondary school in Sweden, where mathematics teaching is dominated by solving routine textbook tasks by following prescribed rules. The 38 students in our study can be regarded as novices in the inquiry context. Besides the distance formula as a specific learning objective, the activity aims to develop their self-regulatory skills and inspire them and their teachers to pursue further development of these skills. The blending of one-to-one technologies and traditional resources offer invite the students to make meaningful mathematical connections between geometric and algebraic representations.

2. Theoretical background

Current research in psychology [1] suggests a relation between overt behavior and learning gains, where interactive-constructive behavior (exploring, investigating and generating in collaboration with peers) is more favorable than just being active in the classroom, for example, when solving routine problems in a textbook. However, inquiry-based learning [2] (as well as problem-based, learner-centered, discovery, experiential, and constructive learning) is often implemented with minimal guidance from the teacher and has in such cases been shown to be less effective for novice learners than guidance specifically designed to support the their cognitive processing [3]. The successful implementation of inquiry-based learning activities requires careful design considerations of guidance, in terms of embedded features of the activity and carefully planned strategies for teacher guidance and peer scaffolding during the implemented activity [5]. Inquiry-based learning challenges students' self-regulation regarding cognition, motivation, behavior, and context, in corresponding phases of self-regulation: forethought, planning, and activation (cognition); monitoring (motivation); control (behavior); reaction and reflection (context) [4].

3. The mathematical learning activity

In the first task the students work on a clear screen in order to stimulate attending only to geometric relations. The task concerns points equidistant to two given points: *The distance from the point to P should be equal to the distance from the point to Q.* They are instructed to place several such points on the screen (Fig. 1, left pane) and answer the question:

What geometric figure do you get from all the points that satisfy the condition?

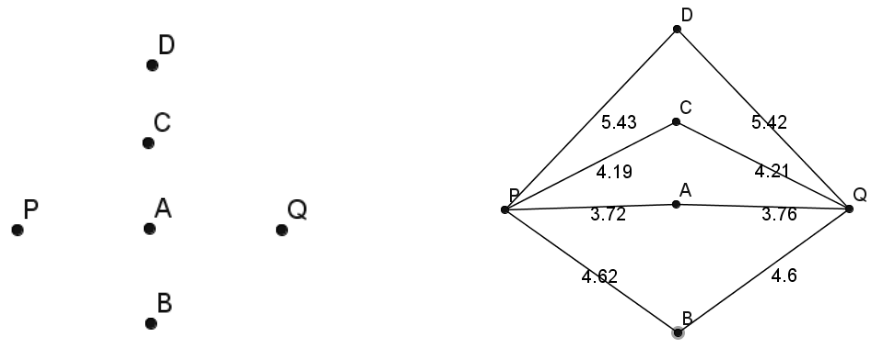

Figure 1: Constructions in GeoGebra according to the instructions for the first task.

Next, the students are invited to check the placement of their points by having GeoGebra measure the distances from each point to P and Q, respectively (Fig. 1, right pane).

The second task addresses the same geometric condition and the same question, but now in a coordinate system. The students are instructed to keep their constructs from the first task, show grid and axes, and place the points at P = (0,4) and Q = (2,0) respectively (Fig. 2, left pane). A correct reconstruction is illustrated in Figure 2 (right pane).

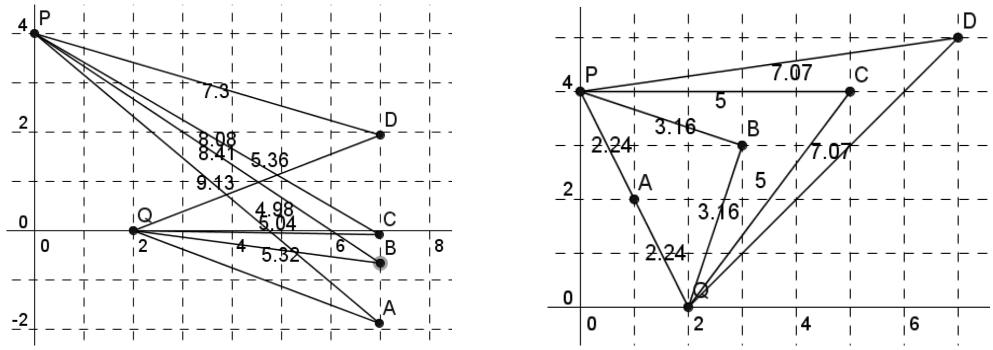

Figure 2: A possible initial setup (left pane) and a correct construction (right pane).

On the next page of instructions the students are asked to work with pen and paper to find the equation of the straight line.

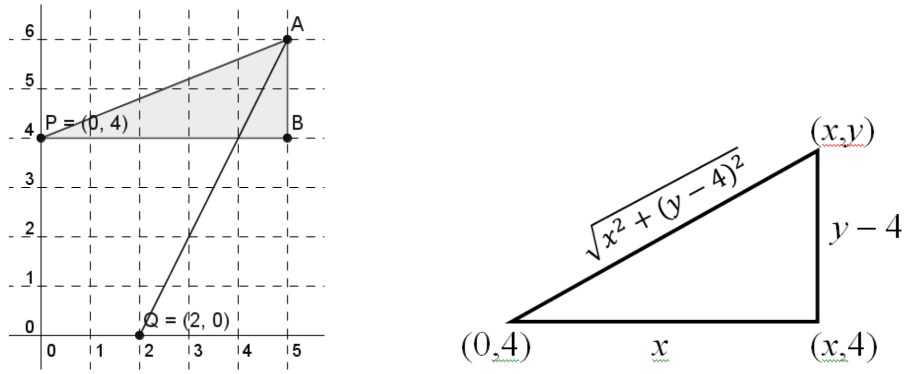

Figure 3: Continuation of task 2 in Geogebra (left pane) and on paper (right pane).

So far, the students have been acting on definitions by interpreting and representing them, generalizing from a few points to all points, justifying geometric constructs, and acting on a generalization of a visual representation by representing it algebraically. The continuation of the second task is more challenging. The students are asked to *prove algebraically that all the points (x,y) that satisfy the condition lie on a straight line*. They are instructed to implement the setup shown in Figure 3 (left pane).

They draw the triangle PAB in GeoGebra (Fig. 3, left pane) and work with pen and paper to find an algebraic expression for the hypotenuse (Fig. 3, right pane). They are also asked to find an expression for the distance between A and Q and simplify the equation:

$$\sqrt{(x-0)^2+(y-4)^2}=\sqrt{(x-2)^2+(y-0)^2} \quad \text{yields the equation} \quad y=\frac{1}{2}x+\frac{3}{2}$$

The students who finish readily recognize that the last equation defines a straight line.

4. Main results and concluding remarks

In task 1, several groups initially answered ‘a cross’ or ‘a triangle’, even after they had constructed the line segments that allowed them to measure distances. The picture (Fig. 1) was prioritized before the written condition in the students’ reflections, which may be considered as a misinterpretation of the available contextual elements.

In the final part of task 2, the students made several algebraic mistakes such as 1) replacing the square of a binomial with the sum of the squares of the two terms and 2) canceling square roots and squares term by term. They did not activate any strategies for self-control and had to be told by the teacher to check their incorrect calculations.

Several students who got stuck while working with the tasks showed signs of lacking motivation. However, they recovered quickly when receiving content-oriented guidance.

In a classroom environment where students mainly solve problems in a textbook, most mistakes can be easily adjusted by checking answers or asking peers or the teacher. In such an environment, individual students are not responsible for monitoring, control, and reflection on their work. Mistakes do not propagate and do not affect future work, so they are not stimulated to develop strategies for self-regulation. In comparison, even a minor mistake in an inquiry can have fatal effect on its continuation and may cause the students to fail in achieving the intended learning objectives. Sensitively guided inquiries can serve to nurture not only mathematical learning but also self-regulation. The 38 participating students in our study show good promise, they just need to be offered more frequent opportunities to engage in carefully designed and meaningful mathematical inquiries.

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