TI's Nspired Mathematics

Connections Between Algebra, Geometry and Calculus

SNM Conference, Radom – Poland, January 25th, 2009

ABSTRACT: TI-Nspire is the new generation of graphing technology developed by Texas Instruments. Unlike previous graphing calculators, or even most computer software, it allows a dynamic linking between the multiple representations of the same mathematical objects: geometric, algebraic, numeric... In this workshop we'll present TI-Nspire as a powerful tool to teach mathematics and perform an activity that explores these connections. We'll do that in a practical manner, using TI-Nspire to answer the ancient maximization problem of finding, from all rectangles with the same perimeter, the one with maximal area. So, we shall create a rectangle of fixed perimeter, see how the area changes as we animate the rectangle, capture data to a spreadsheet and plot the data. It will, with no surprise, suggest a parabola, so we'll define a 2nd degree function and then model it to the data and finally determine the maximal area.

DURATION: 3 hours.

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Part I – Basic Concepts

1. What is TI-Nspire

TI-Nspire is the new generation of learning tools developed by Texas Instruments. It's available as a handheld but also as a computer software. They both have the same capabilities and files created in the computer software can be sent to the handheld and vice-versa.

There are two different TI-Nspire versions: the numeric version (blue handheld) that does not allow symbolic manipulation, and the Computer Algebra System (gray handheld) that allows symbolic manipulation. Again, they are compatible and a document created in a CAS version can be sent (and used) in the numeric version. The only limitation is that whenever a symbolic function is needed, the numeric TI-Nspire will produce an error.

It was designed as a tool for teaching and learning mathematics and sciences and was developed with the input of hundreds of mathematics and science teachers worldwide. And it allows us to explore the different aspects of a problem (algebraic, geometric, analytical, numerical), in a unified manner.

One problem, multiple representations! So we can start with a geometrical construction, extract numerical data from it, analyze it and then plot a function do fit the data. In this workshop we will do precisely this: use TI-Nspire to solve a classical area maximization problem: which rectangle, of given perimeter, has the maximal area?

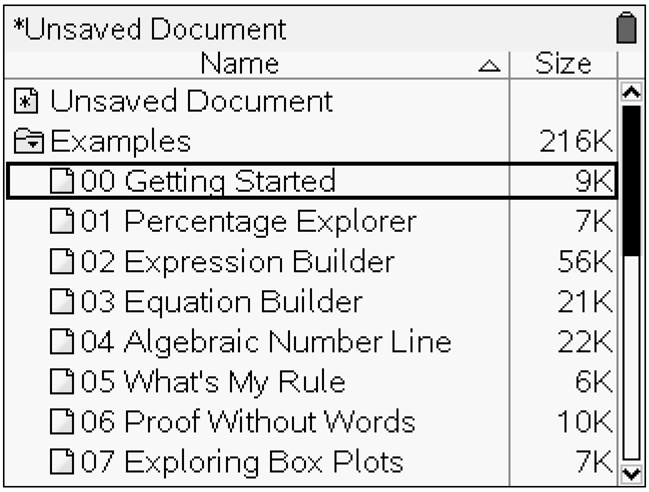
But first, one should get acquainted with TI-Nspire and its interface. On the next pages we'll cover the very basics of working with TI-Nspire: document structure, keyboard, basic navigation and menu system.

Then we move to the activity itself. The goal of the activity, more than to solve the problem, is to explore as many features of TI-Nspire as possible. Along the way you'll learn about many of the available tools and some advanced features, as well as others, simpler ones.

The activity is thoroughly illustrated, allowing the reader to follow through the procedures more easily.

2. Document structure

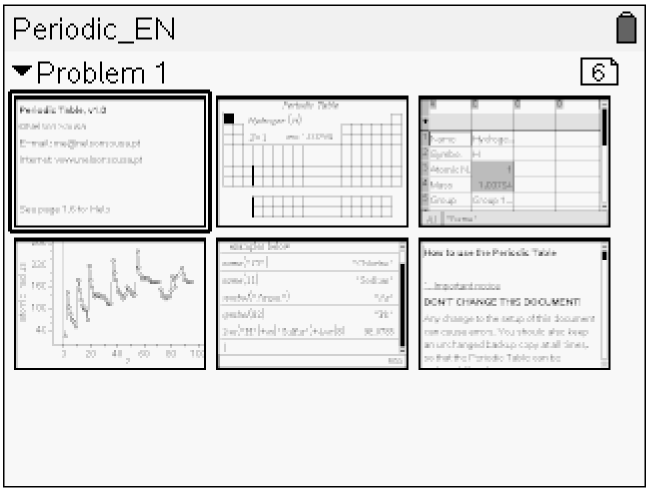
One's work on TI-Nspire is organized in documents. Just like in any other computer application we create documents where we build our work which can then be saved, copied and distributed to others.



On TI-Nspire handheld we have a **My Documents** folder, where documents are stored. In the computer software documents are stored in the **My Documents\TI-Nspire** folder.

Inside **My Documents** we can create folders, to better organize our work and in each folder we can save our documents.

In the first picture we have an *Unsaved Document*, that's the document we're currently work on, then a folder called **Examples** and in it several documents. Each document has one or more pages of content: calculus, graphics, geometry, spreadsheet, etc. These pages can be organized into **Problems**.



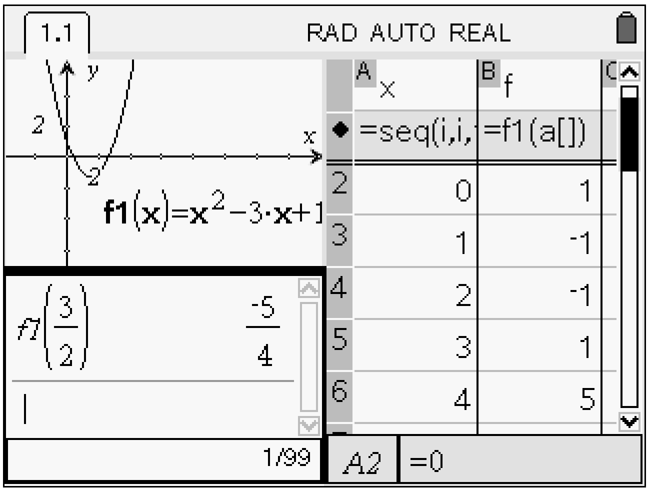
All these pages can be viewed on the **Page Sorter** view. They can also be arranged, duplicated and deleted in this view.

The document depicted at the right has 1 problem and 6 pages.

Each page contains **Applications** and can consist of a single application or up to 4 applications simultaneously in a split screen.

There are 5 applications to choose from:

- Calculator
- Graphs & Geometry
- Lists & Spreadsheet
- Data & Statistics
- Notes



At the right you can see a split page with 3 applications: a Graphs & Geometry application with the graph of a quadratic function, a Lists & Spreadsheet application with the function's values and a calculator page where we can compute particular values of the function.

2. The keyboard

We navigate through TI-Nspire's documents, pages, applications, menus, functions, etc. using the keyboard. At first glance it may appear rather complicated, as it's much different from previous graphing calculators. It is, however, much simpler to use, more flexible, and intuitive.

We can divide the keyboard into different sections:

- **Numeric keyboard:** the white keys at the center columns of the keyboard, on the bottom: numbers 0 to 9, decimal point and sign change key.
- **Operations keyboard:** located around the numeric keyboard: arithmetic operations, trigonometric functions, exponential, logarithm, powers, roots, etc.
- **Secondary keyboard:** small green keys with letters A through Z, some special characters, (π, θ, i, EE) punctuation keys (,, ␣, ?, :, ↵), comparison symbols (<, >, =) and the special International key, ⚐.
- **Navigation keys:** these keys allow access to the main menus of TI-Nspire, as well as navigation through TI-Nspire's interface. They're located on top of the keyboard: the round 4 direction cursor, the center button, ☟, and the Home (⌂), Menu (menu), Tab (tab) and Esc (esc) keys.
- **Special keys:** These would be the off/on, enter, ctrl, and clear Keys, located on the corners of the main keyboard, but also CAPS ⇧ (to type in uppercase letters), sto→ var (to access the variable list) and ∞β (function catalog).

One key is of crucial importance: the ctrl key. Most keys have a blue symbol or character printed either on the key itself or just above it. It's the key's secondary function. For example, the ⌂ key has the 🔧 symbol printed over it. This symbol refers to the **Tools** menu, and can be accessed by pressing ctrl and then ⌂. Note that one doesn't need to press both keys simultaneously. Just press ctrl, release it and press ⌂ and you access the Tools menu.

When we press ctrl the screen displays **CTRL** in small letters on the upper right corner (at the left of the battery indicator). That means that the next key pressed will execute the secondary function. If we press ctrl again the indicator disappears.

The same happens with the Shift key, CAPS ⇧: pressing it we see a small arrow on the upper right corner, meaning that the next letter we type will be uppercase. By pressing ctrl + CAPS ⇧ we activate **CAPS LOCK**, meaning that all letters will be typed in uppercase until Caps Lock is deactivated.

4. Basic navigation

As was mentioned above, a TI-Nspire document is made up of pages, and pages contain applications. One must know how to go from one page to the other, how to open another document, start a new document, etc.

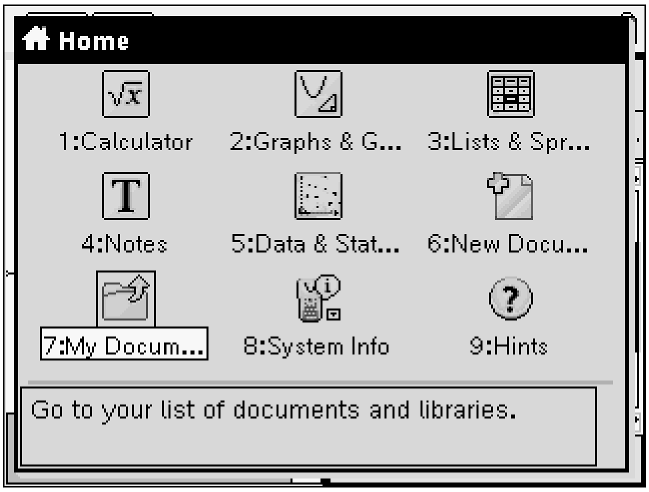
By pressing ctrl+LEFT we move to the previous page, and ctrl+RIGHT takes us to the next page (we can see the page numbers on top of the screen: 1.1, 1.2, 1.3, 2.1, etc. The current page number appears in white as other pages appear in gray).

To go from the page view to the page sorter and then to My Documents we use ctrl+UP. ctrl+DOWN takes us the other way, from My Documents to the page sorter and from there to the page itself.

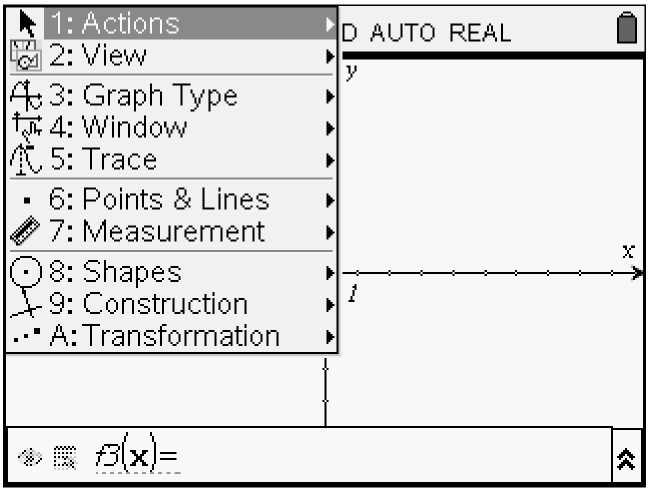
The other two main keys for navigation are tab and esc. The tab key allows us to move from one location to the next. For example, when a dialog box is open, pressing tab takes you from one selection box to the next (**Tip:** pressing CAPS ⇧+tab move the opposite way). And to leave a menu and go up a level, or to exit a selection box without confirming the changes, we pres esc.

The Home Screen
By pressing ⌂ we go to the **Home Screen**. From there we have shortcuts to add new pages with the different applications available (1-5), create a new document (6) or go to the My Documents folder (7). Also we can access the system's and document's settings (8) and change settings such as angle unit or exponential format.

The Home Screen is a good place to start when getting acquainted with TI-Nspire.

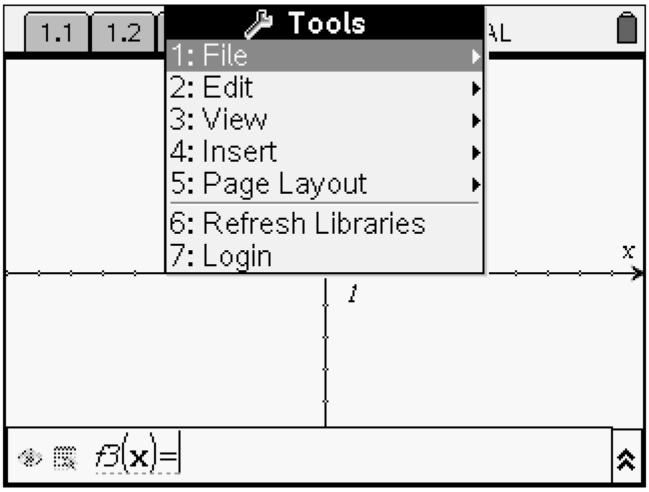


The Application menu and Tools menu
Almost all of TI-Nspire's functions are accessed via the menus. In every situation pressing (menu) will pop-up the **Application menu** with the most important functions available.



Pressing (menu) on the Graphs & Geometry application opens a menu from which you can select the type of graph, define window settings, construct points, lines, circles, etc. On the Calculator application, however, this menu will have different functions.

Another menu, however, is constant in all situations: it's the **Tools** menu. It's accessed by pressing (ctrl)+⌂ (note the 🔧 symbol printed over the ⌂ key) and it allows functions such as saving a document, going to the My Documents folder, cut, copy and paste, insert a page or a problem, change the page layout, etc.



One task, multiple ways
Every task in TI-Nspire can be done, at least, in two or three different ways. For example, to create a new document one can:

- Open the tools menu, Choose **1:File** and then **1:New Document**;
- Go to the Home Screen and choose **6:New Document**;
- Use the shortcut (ctrl)+(N).

Undo and Redo
Perhaps one of the most appreciated functions of TI-Nspire is the Undo feature: by pressing (ctrl)+(esc) (note the ↶ symbol printed over the (esc) key) you go back and cancel your last action. So there's no need to be afraid of doing something wrong, you can always go back! (**Tip:** pressing (⇧)+(esc) will redo, that is, will undo the undo operation).

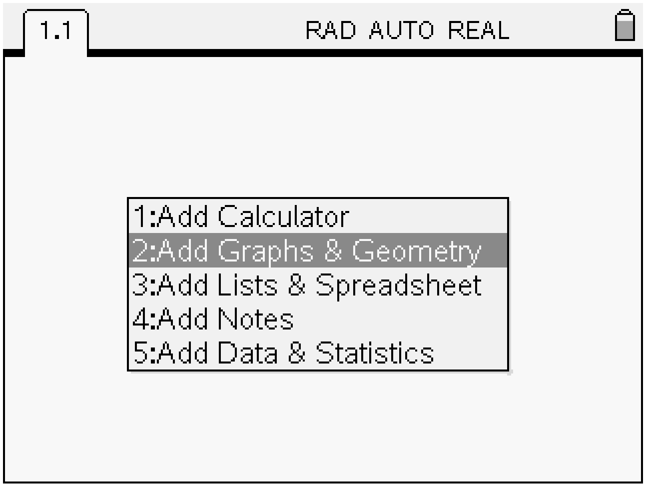
So, let's create a new document and start an activity with TI-Nspire!

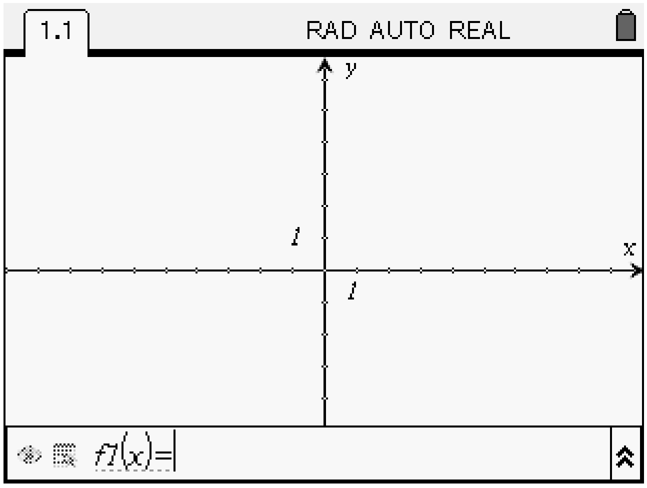
Part II – The activity

Using TI-Nspire we will solve this classical problem: *“Mr. Smith has 20km of fence and he wishes to close a rectangular shaped piece of land to hold some sheep. Which rectangle should Mr. Smith choose if he wants to maximize the area?”*

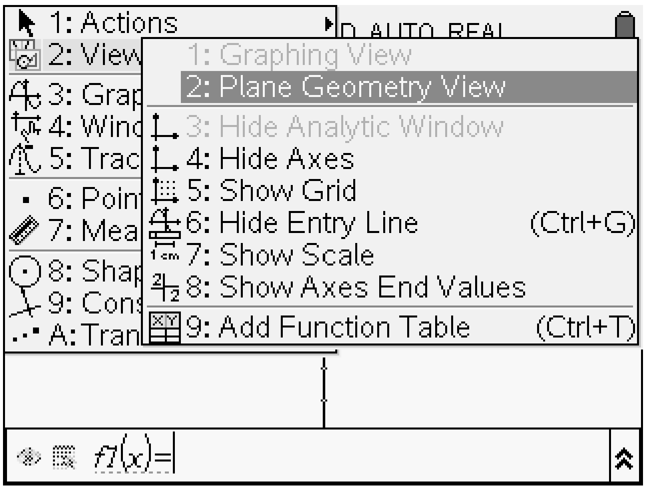
1. Constructing the rectangle

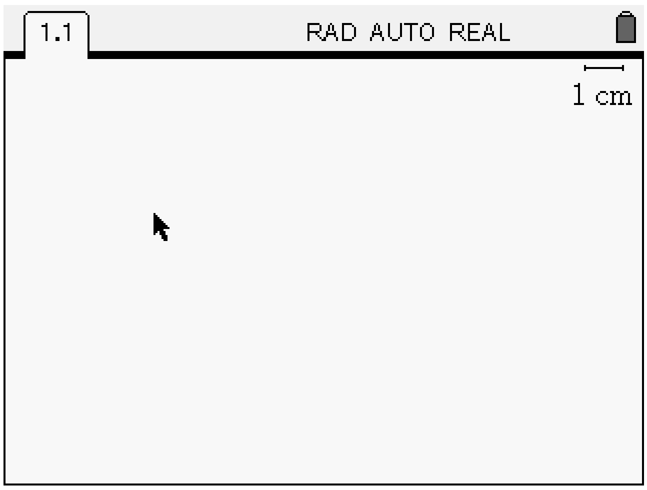
Start by creating a new document, if you haven't done so already. When prompted to add an application select **2:Add Graphs & Geometry**. You know have a graphical window, where you can define and plot graphs of functions.





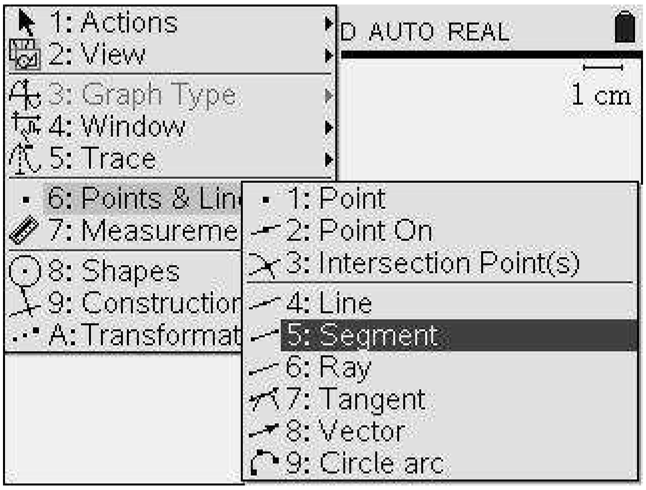
This graphical window is suitable for plotting the graph of a function, but not for Euclidean geometry. In plane geometry we want a circle to look like a circle at all times, while as we plot graphs of functions we usually need to adjust the axis independently, which makes circles look like ellipses. To start a new geometrical construction in plane geometry, without axis or scales to change the look of our construction, press menu and select **1:View** and then **2:Plane Geometry View**.

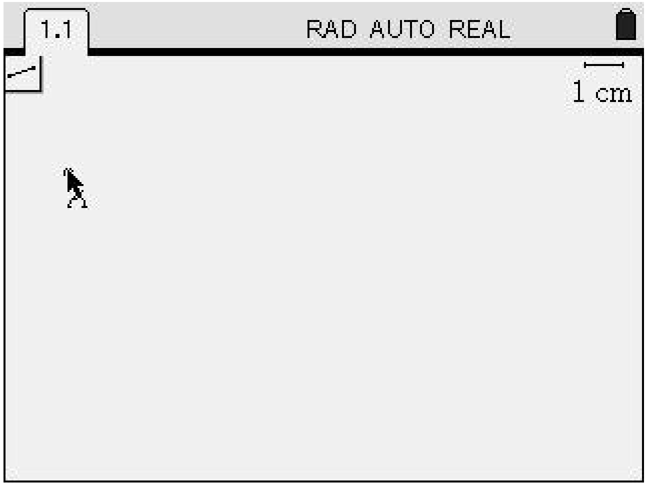




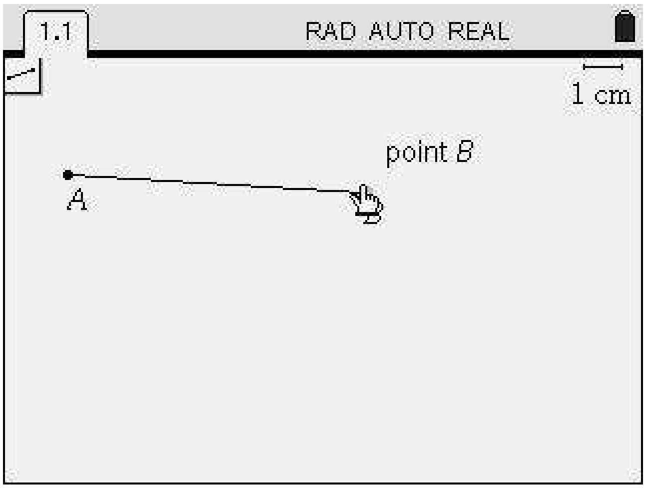
We now have a blank sheet of paper where we can start our construction, building segments, rectangles, perpendicular and parallel lines, etc. We'll first build a rectangle, then impose the fixed perimeter restriction, and finally measure the perimeter, one of the sides and the area to see how it changes with respect to the side of the rectangle.

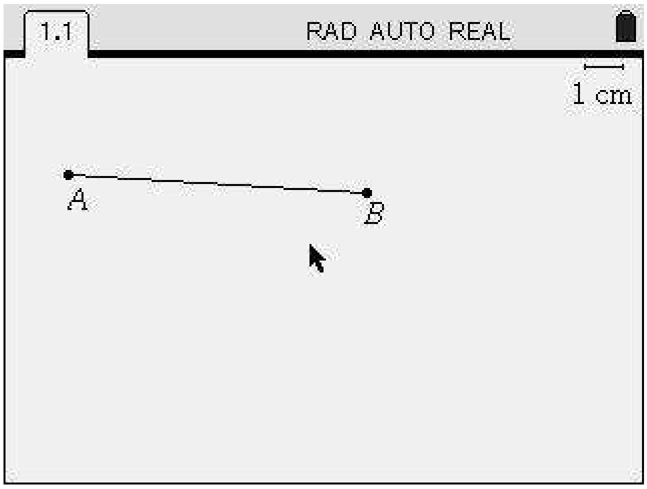
So, lets start by creating a segment and naming it's endpoints A and B. From the **Menu** select option **6:Points & Lines** and then choose option **5:Segment**. Move the cursor do the desired location, click once (press) and type in A, by pressing +A. By typing letters immediately after creating an object we label it. If we don't do that while creating the objects we can do it later, using the Text tool.





Now move the cursor to a different location, click to create the second end point and type in B. When the segment is complete note that the cursor changes to . This is because the segment tool is still active (note the icon on the upper left corner). Press esc to deactivate the tool and move the cursor to an empty region of the worksheet.

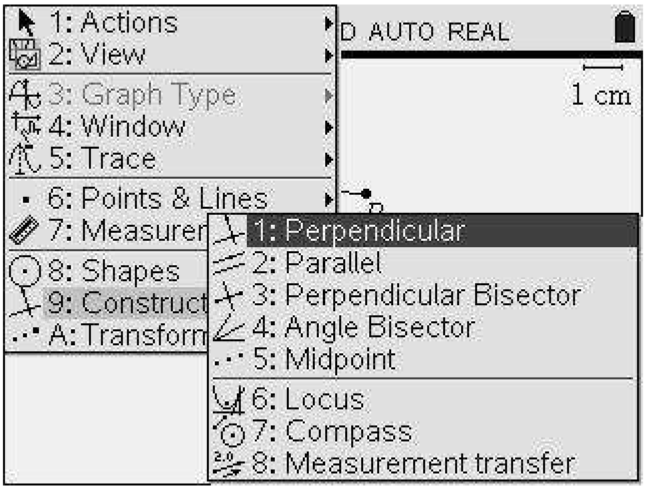


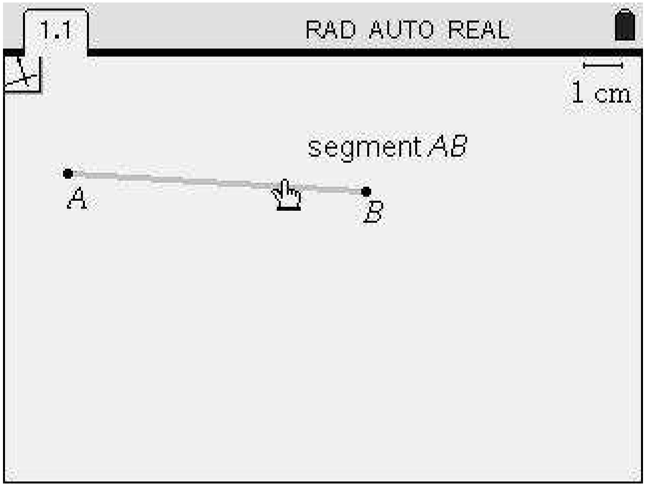


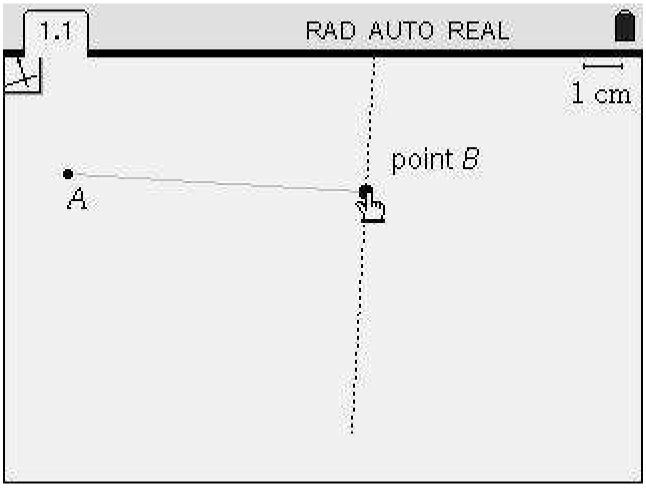
Now select the **Perpendicular** tool from the **Menu**, selecting options **9:Construction** and **1:Perpendicular**. Move the cursor over segment AB and note the pop-up message. These pop-up messages tell you what will happen when you click. So, the message **segment AB** tells you that by clicking you'll be selecting this segment as one of the required objects to construct a perpendicular line.

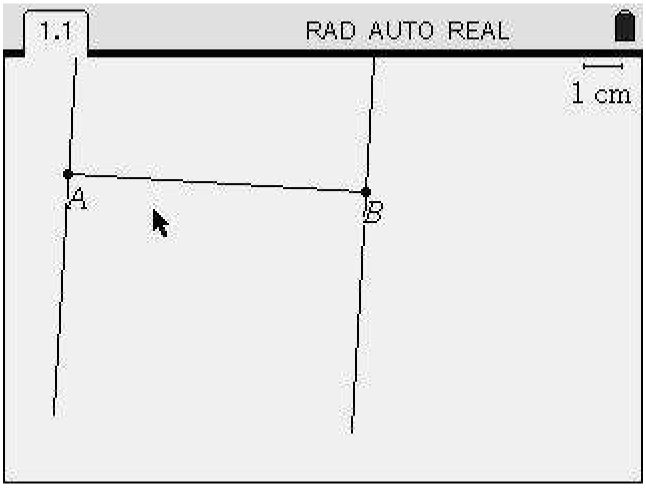
Click to select the segment and move the cursor to point B. Once again, note the pop-up message. Click to select point B. You now have constructed a line, perpendicular to AB and passing through B.

In the same way construct a perpendicular line to AB passing through A. When you're done press esc and move the cursor away to an empty region of the worksheet.

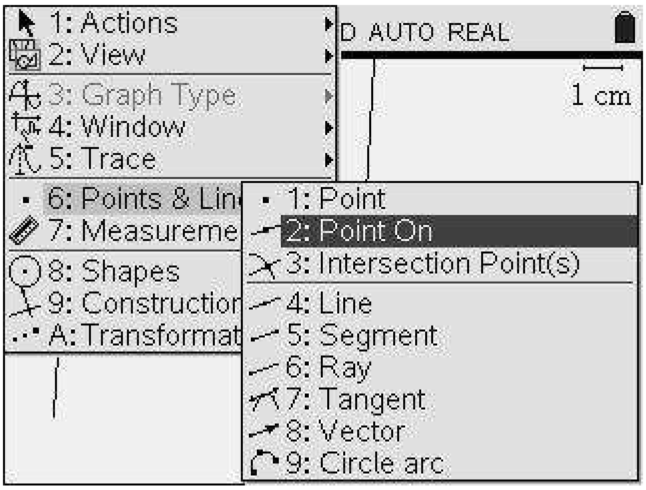


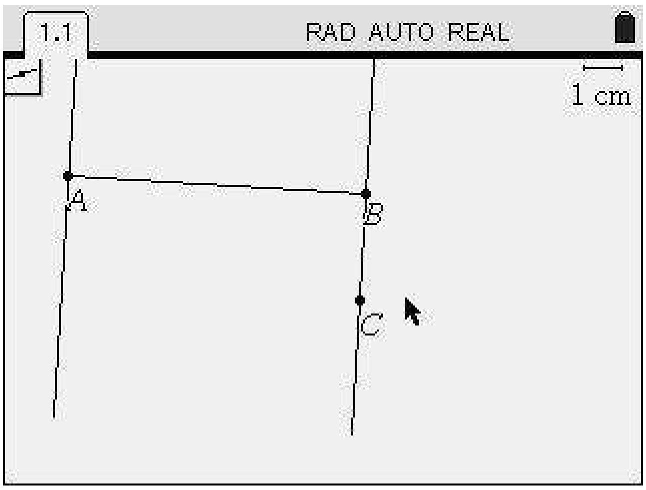






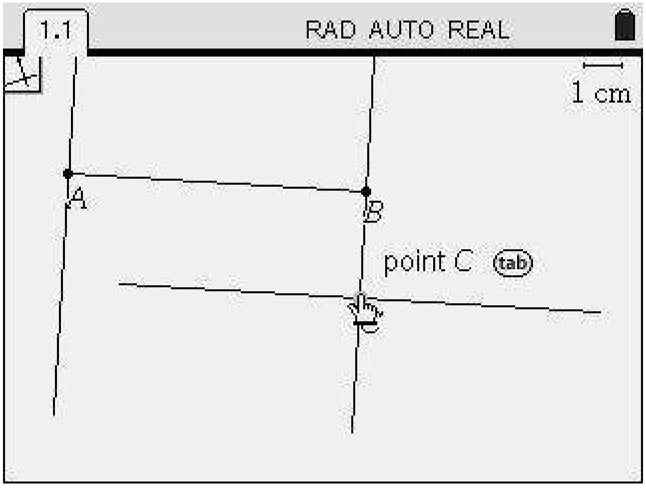
We need now to construct a third point of the rectangle. We'll build point C over the perpendicular line through B with the **Point on** tool. This tool allows you to create a point over an existing object, while not allowing for new points to be constructed on empty regions of the sheet of paper.

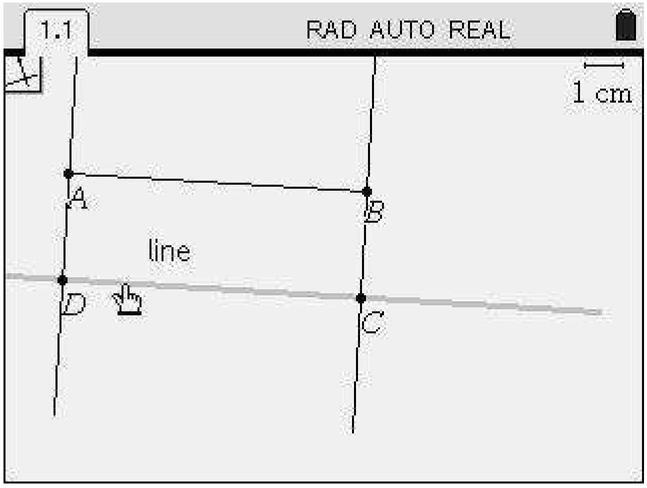




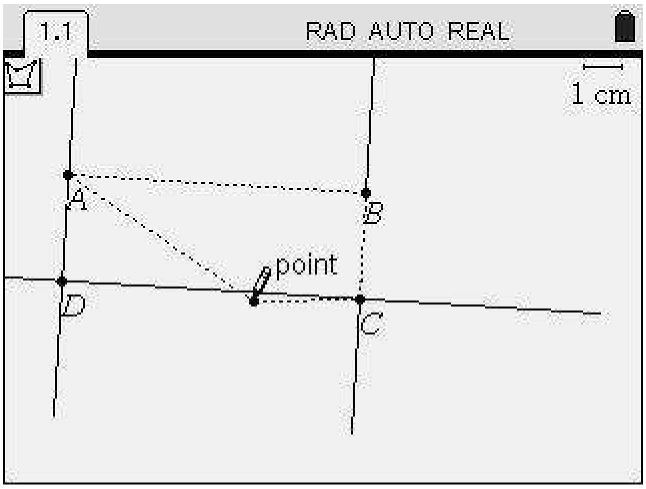
To construct point D we need to build a line through C perpendicular to BC. So, select the **Perpendicular** tool and construct it. **Remark:** to build a perpendicular line you can either first select the segment and then the point by which it passes or the other way around. For most geometry tools the order in which you select objects, as long as they're of different types, is not relevant.

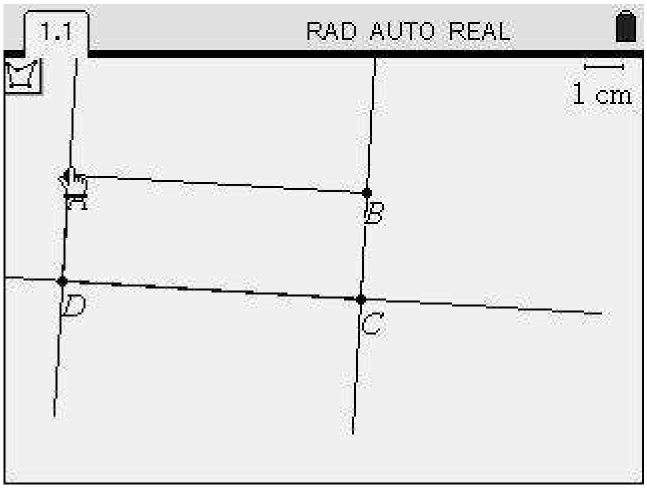
Once built the perpendicular line, point D is determined as the intersection point of both lines, the one though A and the one through D. Construct this point by pressing menu and selecting option **6:Points & Lines** and **3:Intersection Point(s)**. Now click on the two lines and the intersection point will be drawn. Type in D as it's label.





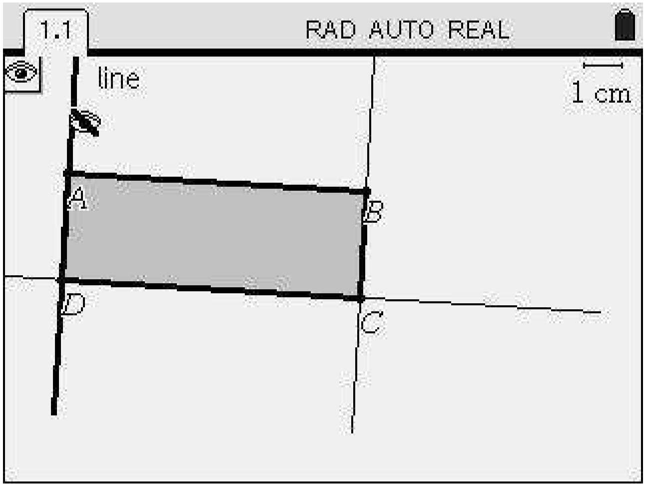
We now have the four points needed to build a rectangle. Let’s do so with the tool **Polygon** (from the **Menu** select option **8:Shapes** and **4:Polygon**). Click on points A, B, C, D and again on A to complete the construction. Beware that you should click only when the cursor changes from to . The pencil means that a new point will be constructed, while the pointing hand means an existing point will be used.

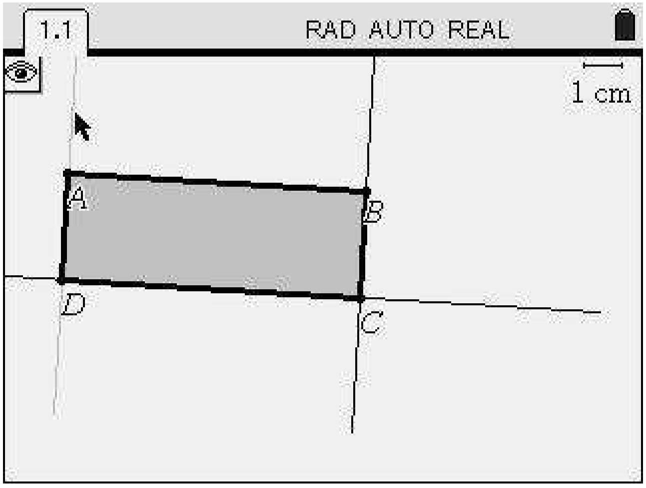




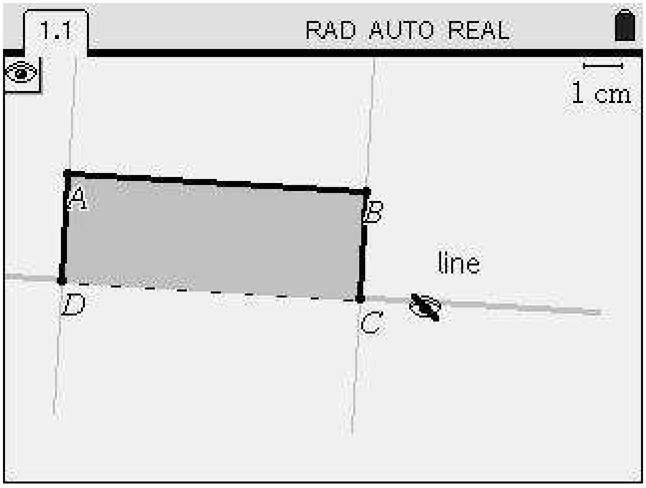
Now that we've built the rectangle we can change it's look (thickness, fill color, line type, etc.) with the **Attributes** tool. Go to the **Menu** and select options **1:Actions** and **4:Attributes**. Move the cursor over the rectangle until you see the pop-up message **polygon ABCD** and click once. Using the arrows change the line thickness to **Medium** and the fill color to **Medium gray**. Press enter to confirm your selections and then press esc to deactivate the tool.

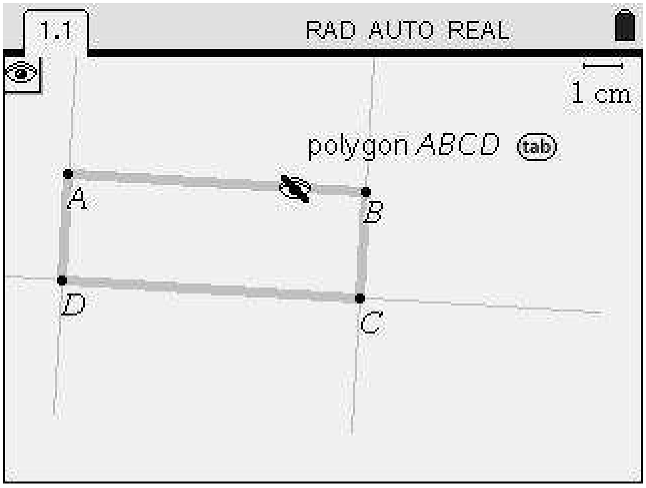
We'll complete this first stage by hiding all unnecessary objects. Segment AB and the 3 lines can be hidden, so that we'll see only the rectangle ABCD. Do so by choosing **1:Actions** and **3:Hide/Show** from the **Menu**. Moving the cursor over an object you'll see a pop-up message with the object name (or type) and the cursor will change to . This icon means that when you click the specified object will be hidden. The object will be drawn in light gray, meaning that it’s hidden. So, hide the three lines (passing through B, C and A) by moving the cursor over them until they start blinking and the word **line** pops-up.

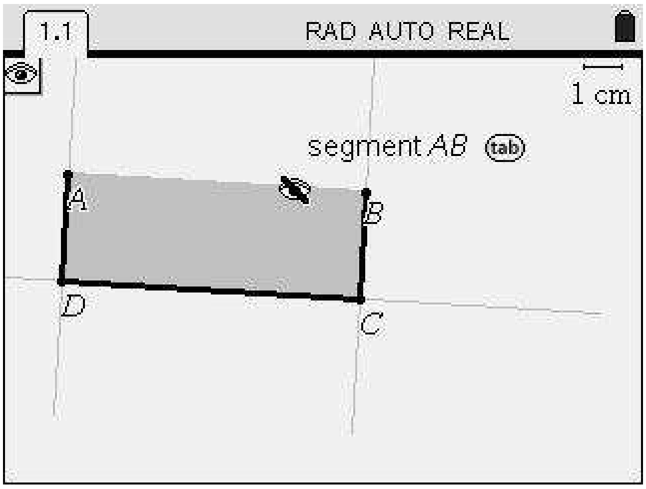


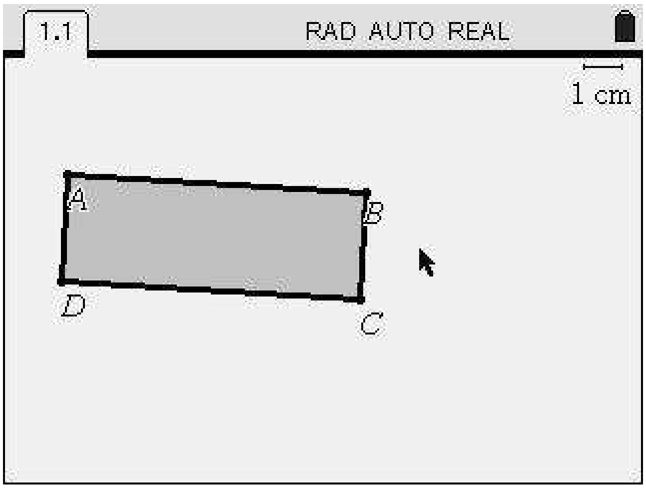


Next place the cursor between points A and B. Note that the pop-up message will display **polygon ABCD** (tab) and the entire rectangle will blink. We don't want to hide the rectangle, only segment AB, so press (tab) to run through the various options available. Pressing (tab) once will cause **segment AB** to pop-up, meaning that you'll hide only this segment, not the rectangle. Click to hide it. Once you've finished hiding objects, move the cursor away and press (esc) to deactivate the **Hide/Show** tool. The **Hide/Show** tool is quite useful to hide auxiliary elements from our constructions and creating nice looking pictures.



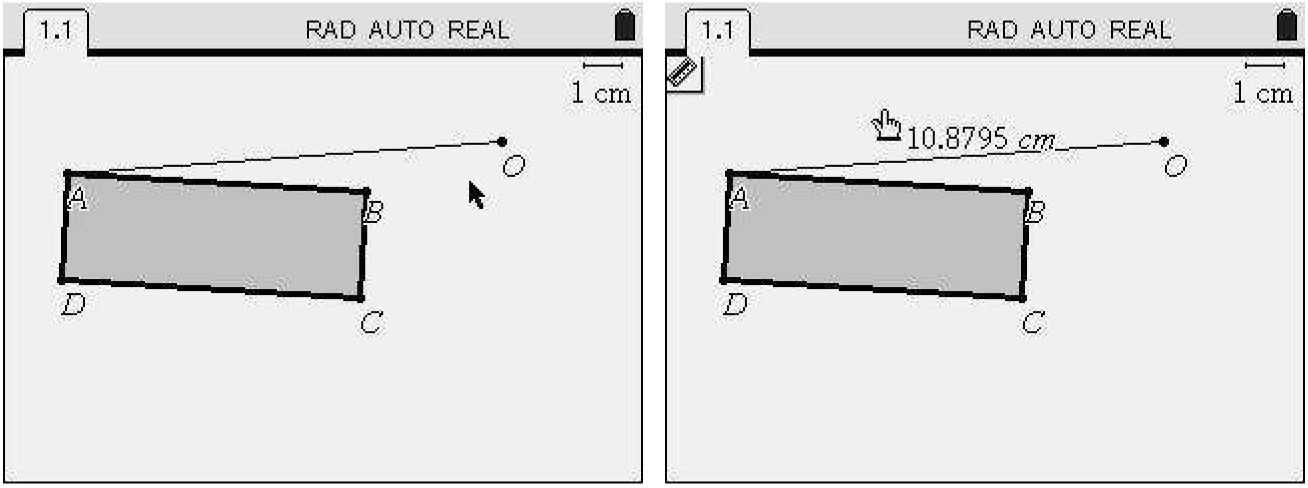




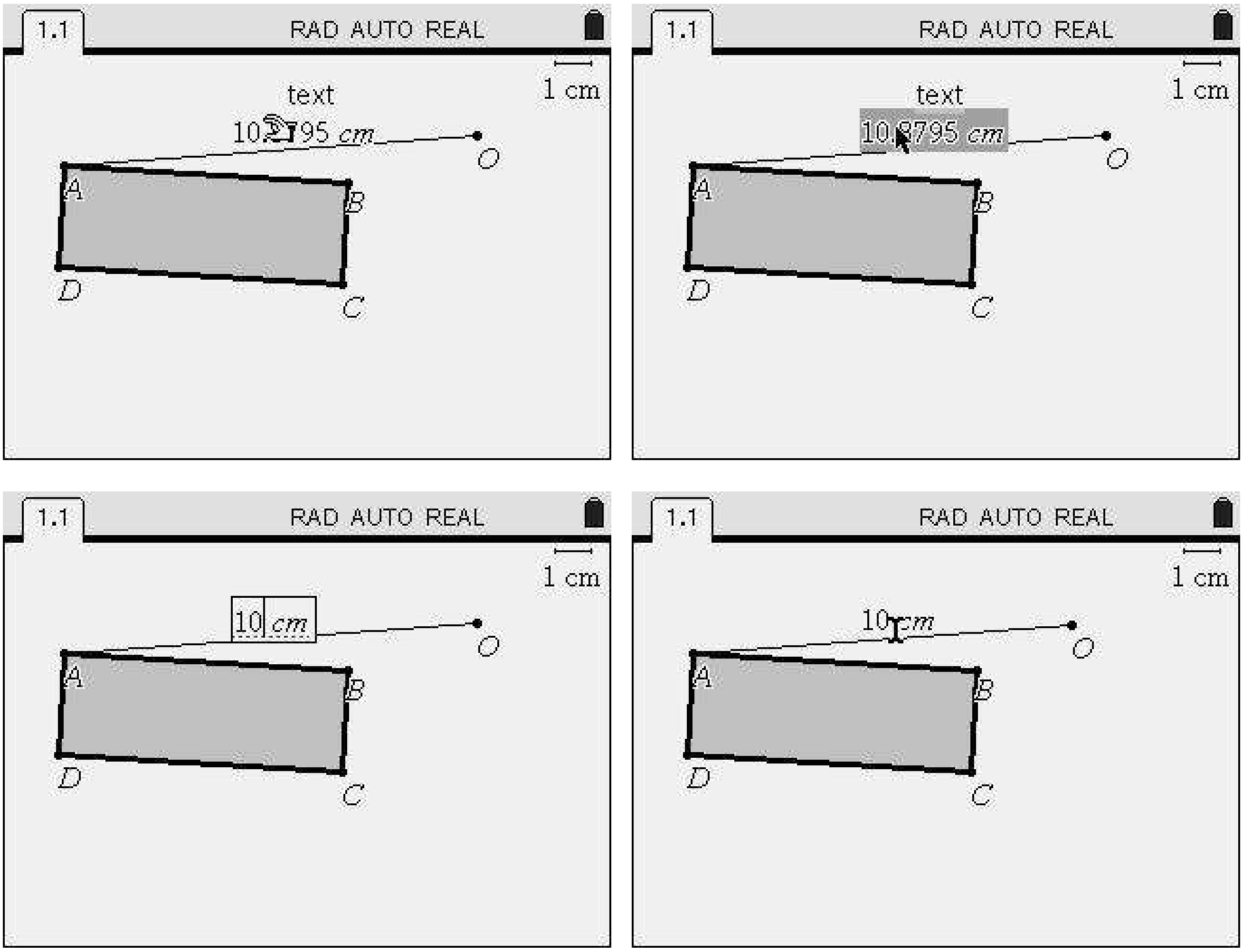


We have built a rectangle, but it doesn't comply with the desired constraint: being of fixed perimeter. We'll do that next.

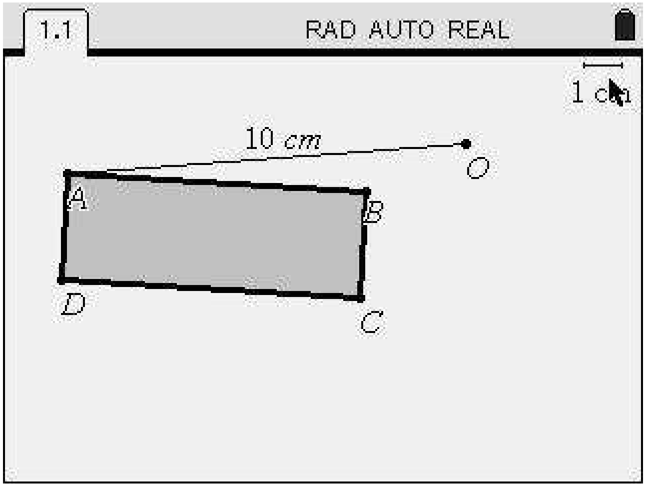
Our problem requires the rectangle's perimeter to be 20 km. We'll start by building a segment, AO, which length is half the desired perimeter. We select the **Segment** tool, place the cursor over point A, click to select it, move the cursor to an empty region, click to create a new point and type in O. Then we measure it's length with the **Length** tool from the **Menu** by choosing option **7:Measurement** and **1:Length**. Click once over the segment AO and again to place the measurement on a desired location.

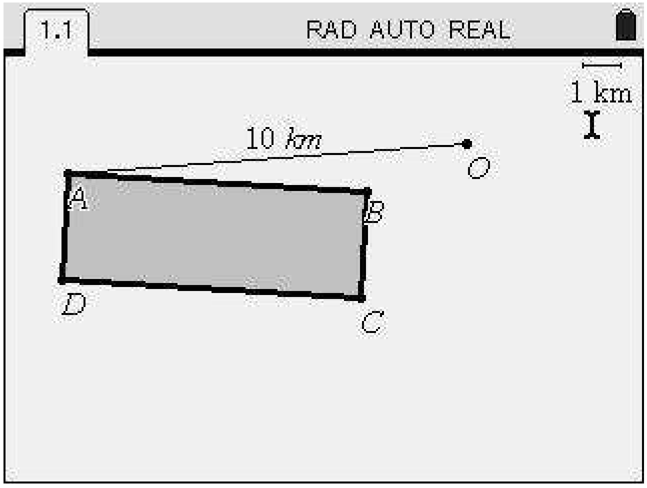


We want this segment to measure **exactly** 10 km. To do so press esc to deactivate the **Length** tool and place the cursor over the measurement. Click once to select it and again to edit. Delete digits as needed and type in 10.

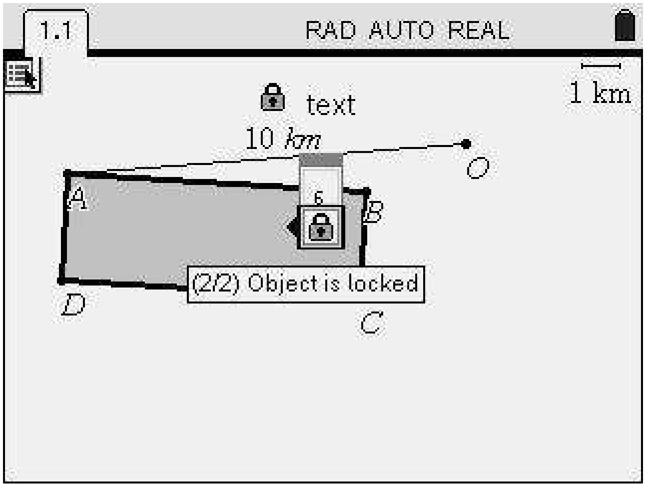


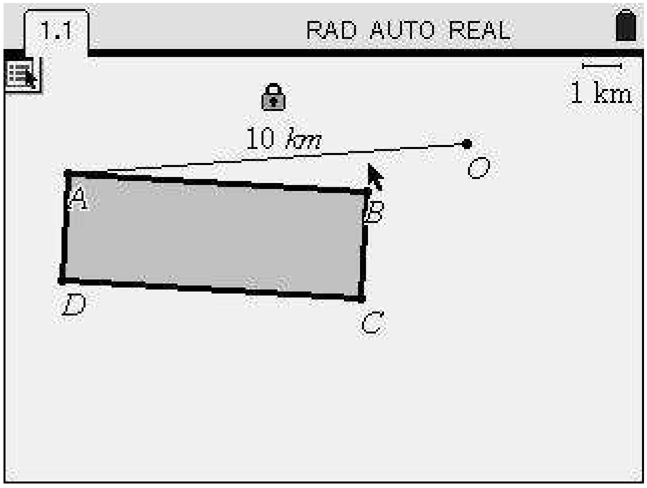
The segment AO now measures 10 cm. We want to change the scale of the problem, having all measurements in km, so we edit the scale (upper right corner of the window). Simply move the cursor over the scale, click to edit, delete cm and type in km (**Remark:** there must be a space between the number 1 and the unit of measurement; so, the scale must read “**1 km**”).





Now all measurements are in Km, giving more realism to our construction. Next, it's recommended that we lock AO, so that its length doesn't change when we move the points around the window. Select **Attributes** from the menu, click over the measurement (not the segment!) and **Lock it**.



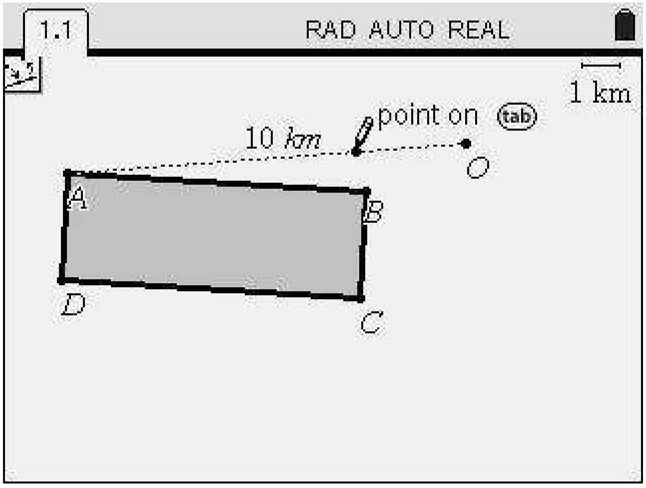


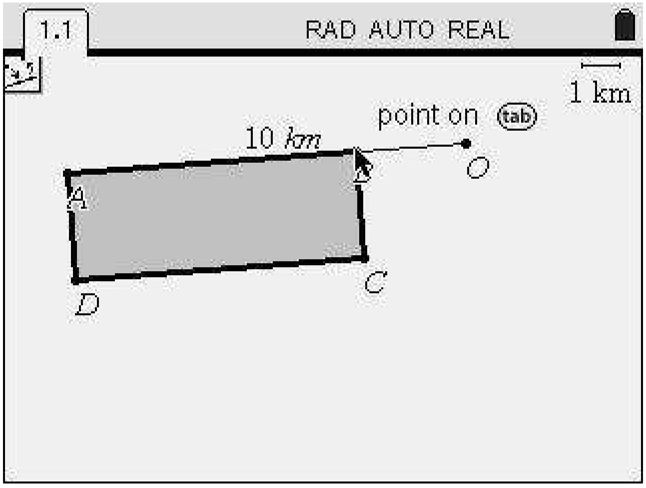
Locking an object means that it cannot be changed by manipulating the construction, unless we unlock it first. That means that if we move point O it will be bound to remain on a circle centered in A and with a 10 km radius, so that AO’s length remains constant.

The next step is **redefining** B so that it lies on segment AO, and redefining C so that BC=BO. This way we'll have AB+BC=10km and the perimeter of the rectangle will be 20 km. As B moves on segment AO so will C in a related way.

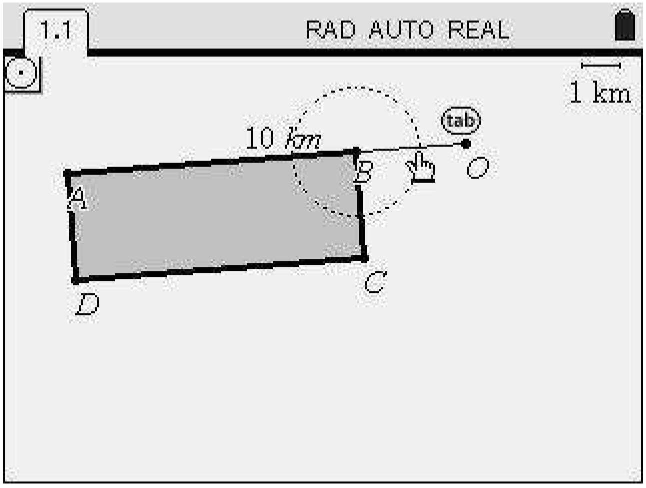
We achieve this using the **Redefine** tool. This tool (from the **Menu** select option **1:Actions** and **9:Redefine**) allows us to change the geometrical properties of an existing object. So, first, select the **Redefine** tool, click on B and then click anywhere on segment AO (the message **point on** will pop-up). From now on point B can move only on segment AO.

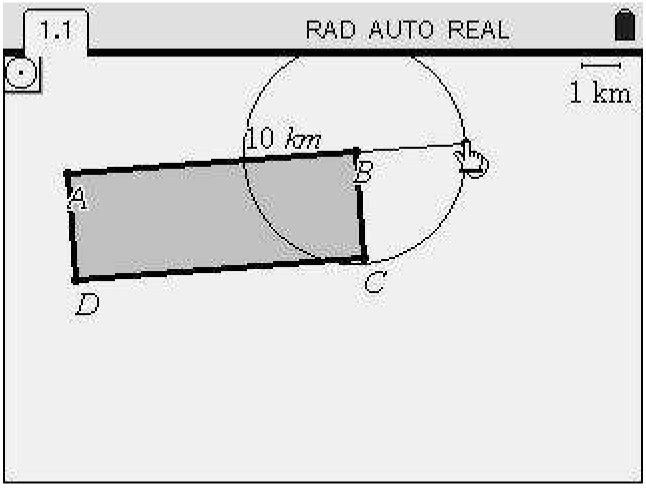
Note that ABCD remains a rectangle, as C was constructed on a perpendicular line to AB and if AB changes, so does the perpendicular line. This is the key point of dynamical geometry: when an object changes, all dependent objects change accordingly.



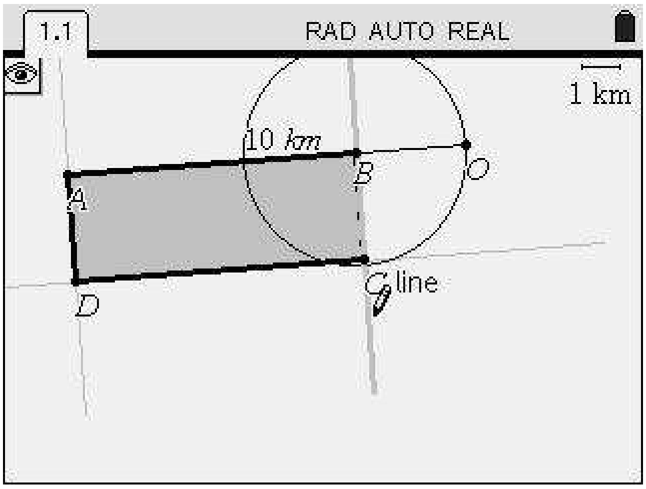


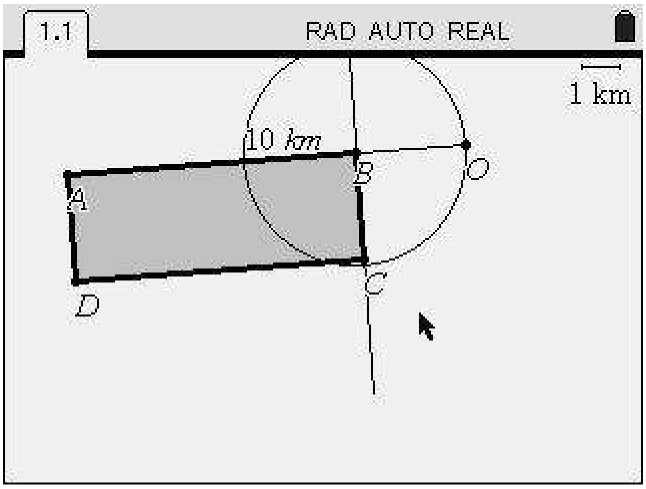
To complete the fixed perimeter rectangle we still need to make BC and BO the same length. For that we construct a circle with center in B and passing by O. Select **Circle** from the menu (**8:Shapes** and **1:Circle**), click once on B to define the center and then on O to define the radius.



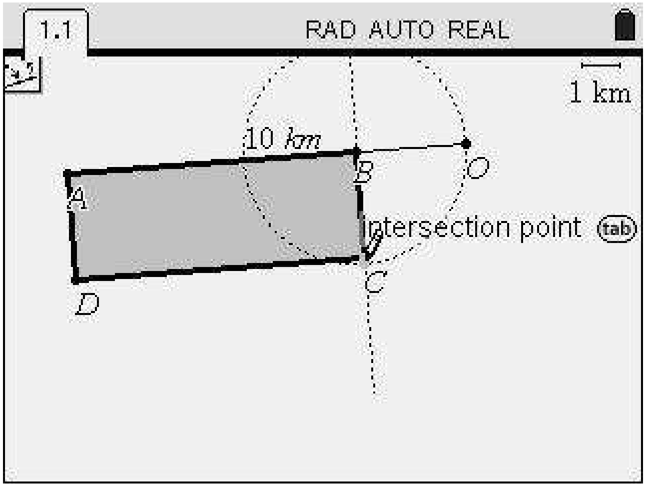


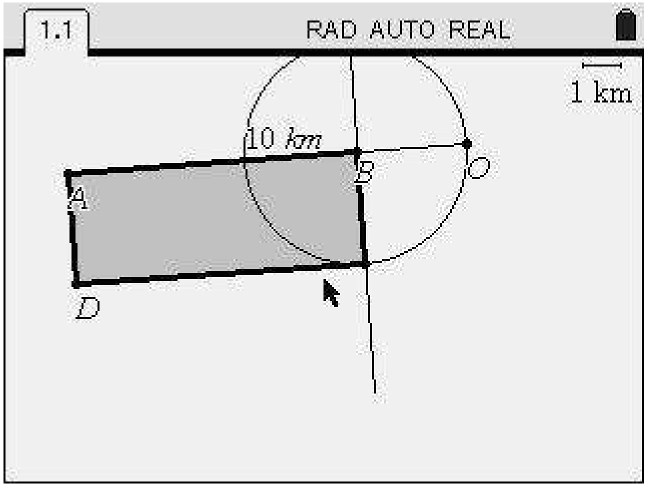
Now we want to redefine C as a point on that circle. However, remember that C was defined as a point on the line perpendicular to AB and passing through B. So, we must use the **Hide/Show** tool to display that line (that we previously hid).



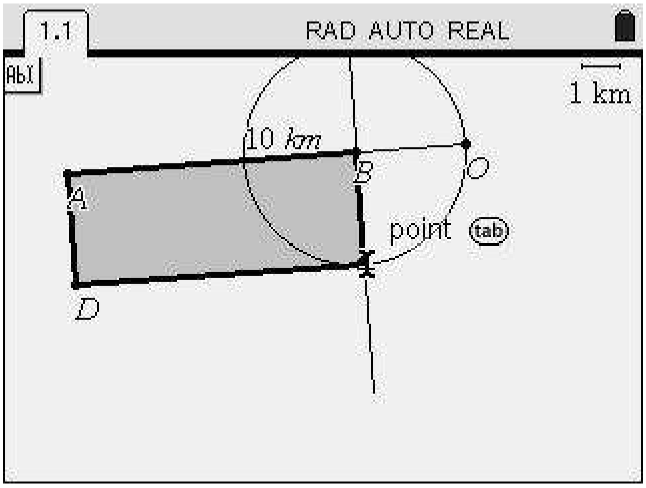


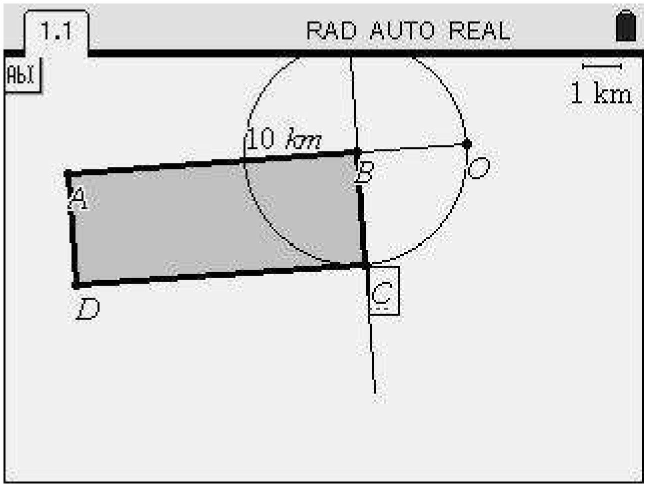
Note that although C looks like it's the intersection point of the line and the circle, this is only apparent. It's only a coincidence that C is near that intersection point. We have to redefine it, using the **Redefine** tool again, clicking on C and then clicking on the intersection point. Note that a message **intersection point** will pop-up meaning that when you click C will be defined as the actual intersection point.





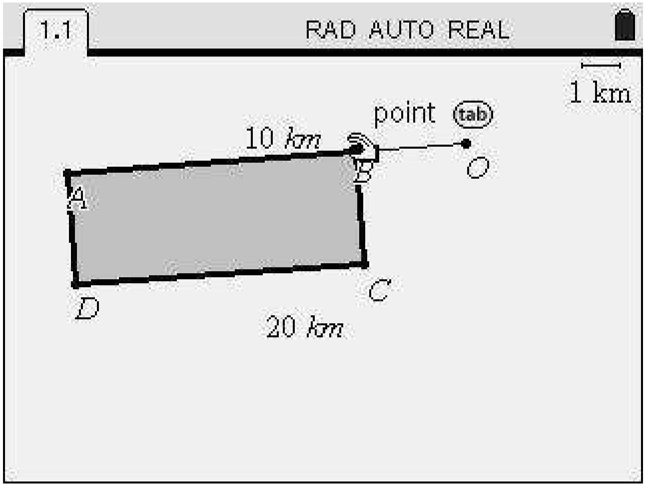
C is now redefined as the intersection point between the circle and the perpendicular line to AB. However, it has lost its label! To add the label again select the **Text** tool from the **Menu** (option **1:Actions**, **6:Text**). Place the cursor over the point (note that **point** should pop-up), click to select, type C (remember to press ⇧ to type in an uppercase letter) and press enter to confirm.

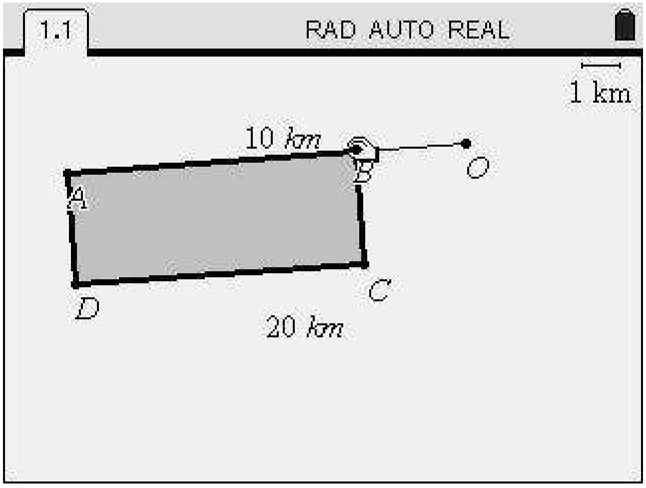


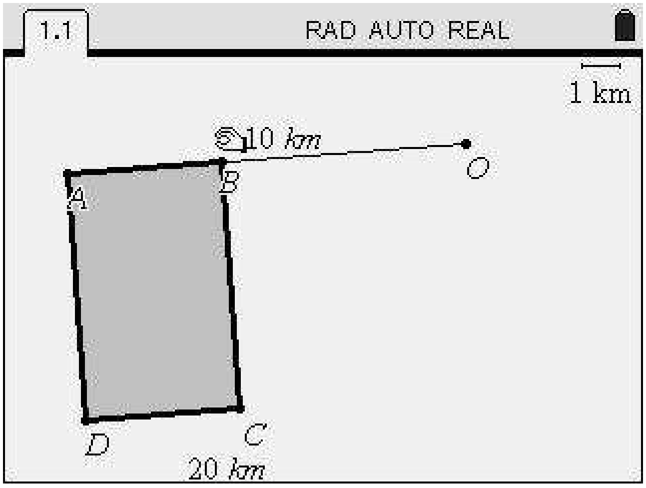


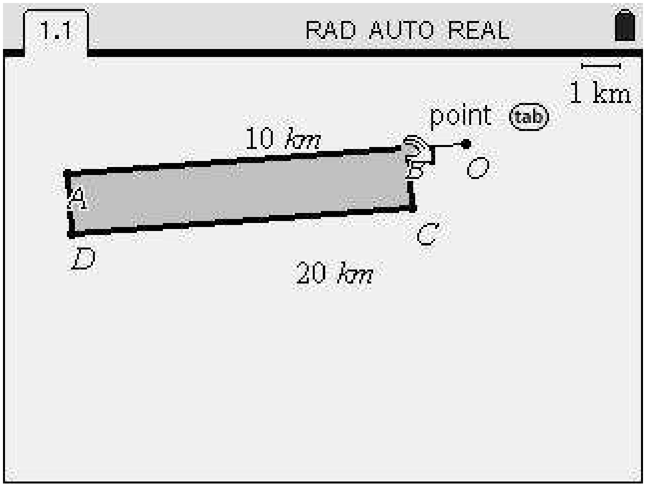
We complete the construction of the rectangle by hiding the auxiliary elements: the perpendicular line and the circle. Now we check that our rectangle is well constructed. We measure is perimeter with the **Length** tool and clicking over the polygon ABCD. It should be **exactly** 20 km. Note that these geometrical constructions are very precise. So if your rectangle has a perimeter other than 20 km you probably have a badly defined point and will need to redefine it properly.

We now move point B along segment AO to check that the perimeter stays at 20 km. We move an object using the **grab&drag** feature of TI-Nspire: press esc to deactivate any previously selected tool and place the cursor over point B. The cursor will change to an open hand, , meaning it's a movable point. We can grab it by pressing ctrl+ or pressing for about 1 second until the hand closes, , meaning the point was grabbed. We now can move it around the construction to another location and release it there (clicking again). The hand will open, meaning that the point is no longer grabbed.



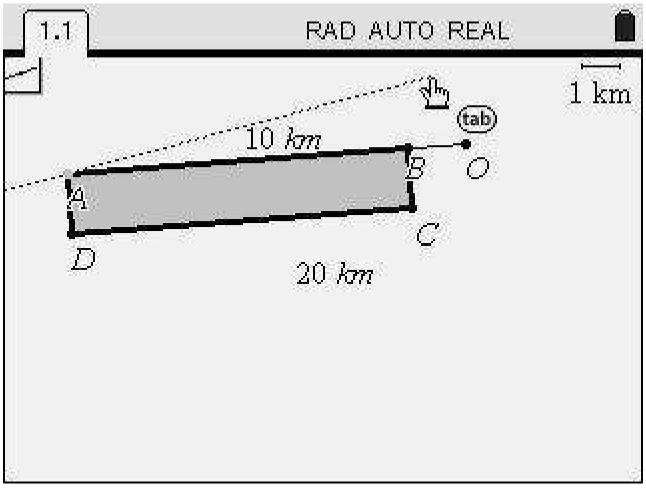


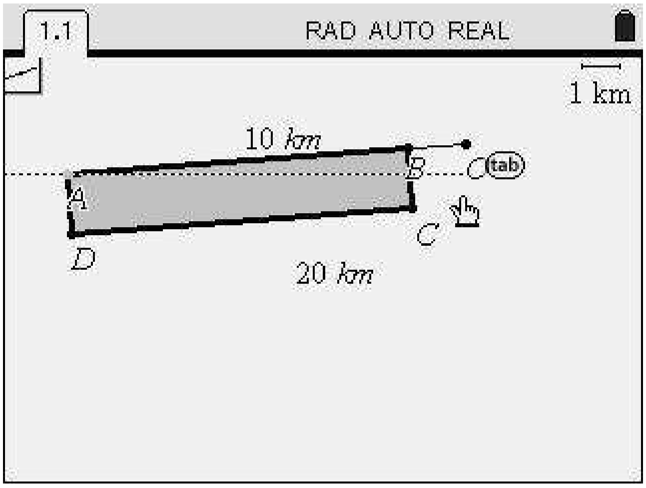




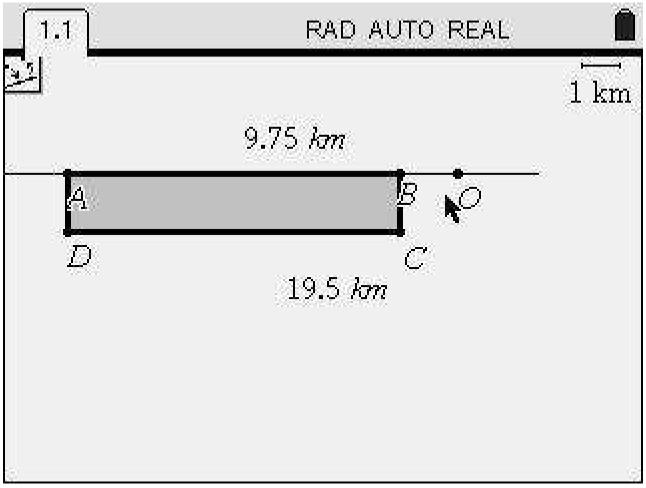
As we can see the perimeter remains at 20 km as B moves. So our construction was successful, and we have built a rectangle of fixed perimeter!

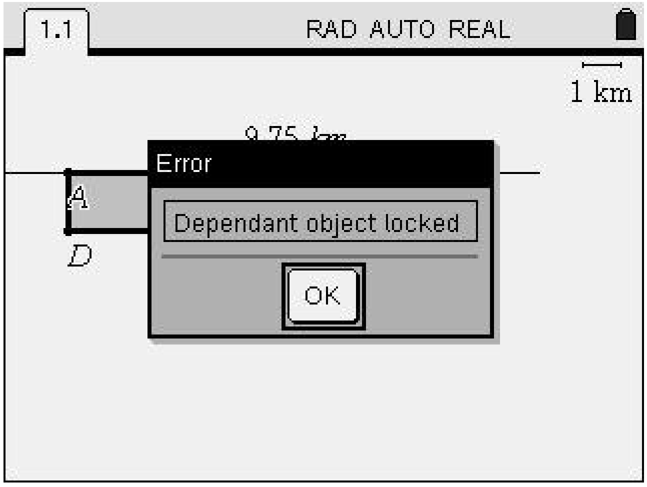
But, although the construction does what we wanted to, it doesn't look that good. The sides of the rectangle aren't horizontal and vertical, which looks much nicer. So, we'll add an aesthetic change and redefine our rectangle as having orthogonal sides, forcing A and O to lie in an horizontal line. We build a line passing by A but forcing it to be horizontal. Go to the **Menu** and select the **Line** tool from **6:Points & Lines**. Click over point A and move the cursor to nearby point O while pressing ⇧. The line will rotate in 15º degree increments. Click to build it when it's horizontal.



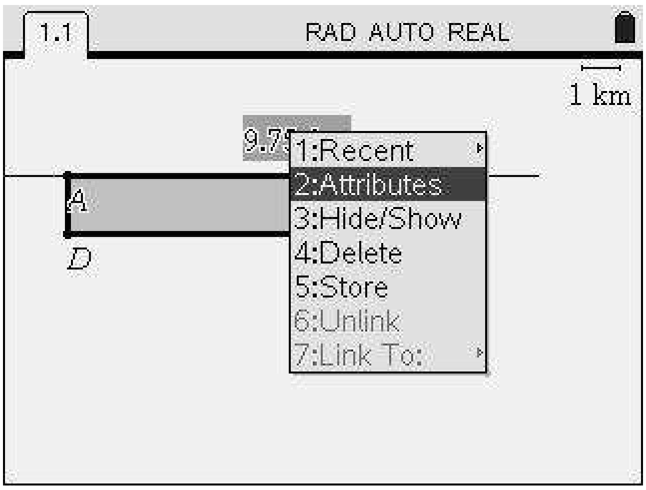


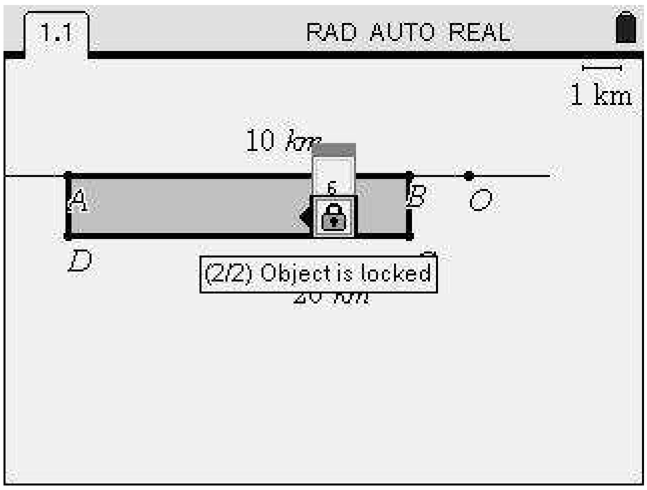
Now redefine point O to lie on this line. By doing so we give our construction a much better look. But now AO doesn't have a length of exactly 10 km, because O was redefined. If we try to edit it back to 10 km again we get an error: *"Dependant object locked"*. Before changing it back to 10 km we must unlock it.

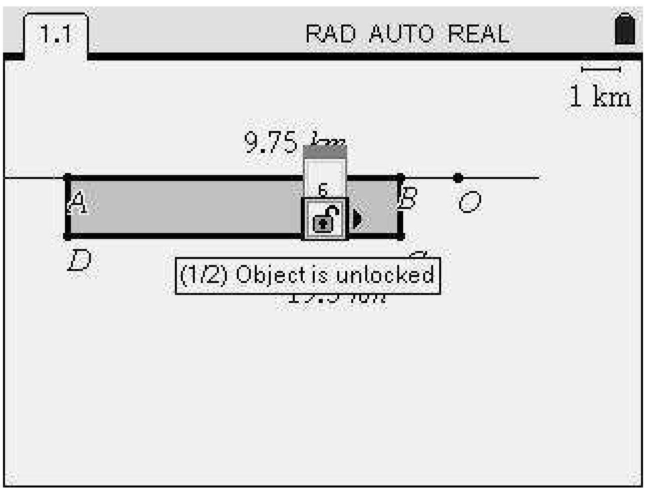


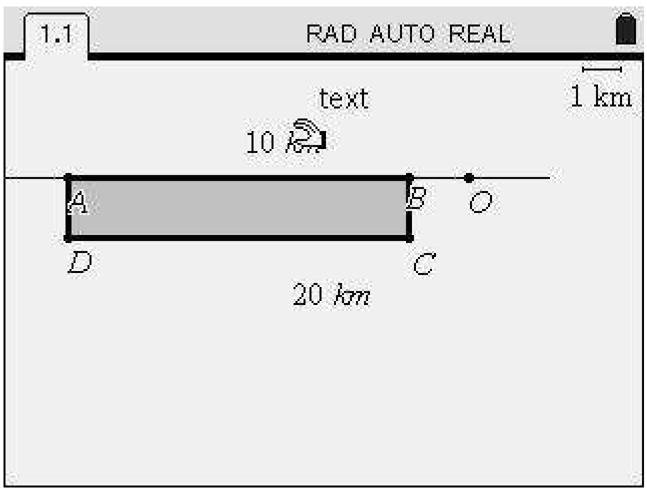


To quickly access an object's attributes we can use a shortcut: the **Context menu**. The Context menu is accessed by pressing ctrl+menu (note the icon) over an object. It contains some functions or features that are relevant for the object in question. So, pressing ctrl+menu when the cursor is over the length of AO we quickly access the **Attributes box** for that object. Open it and unlock the number. Then edit it to 10 km, go back to the Context menu, open the Attributes box and lock it again.

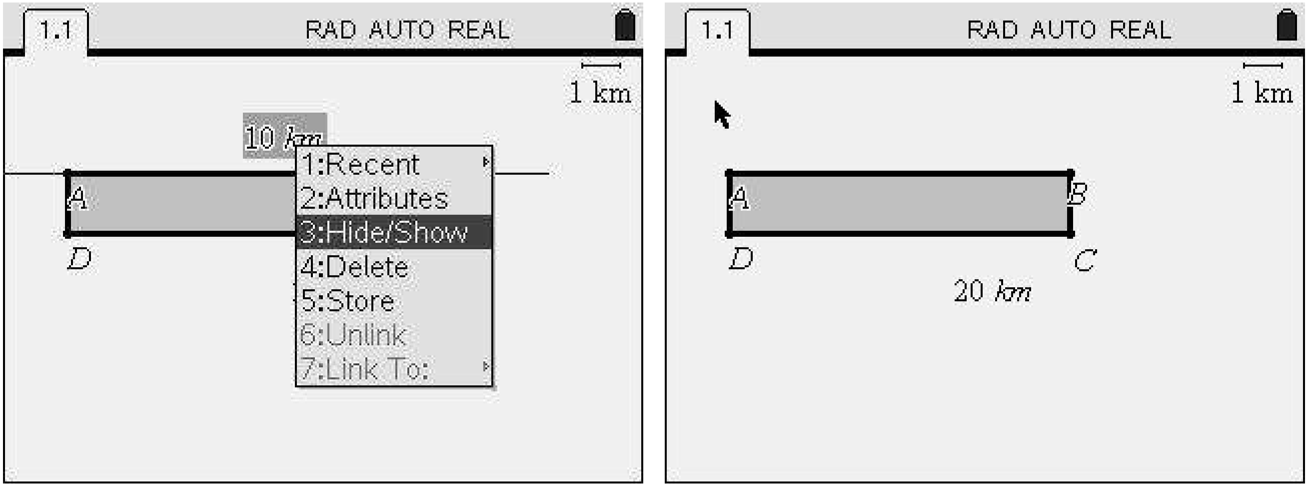




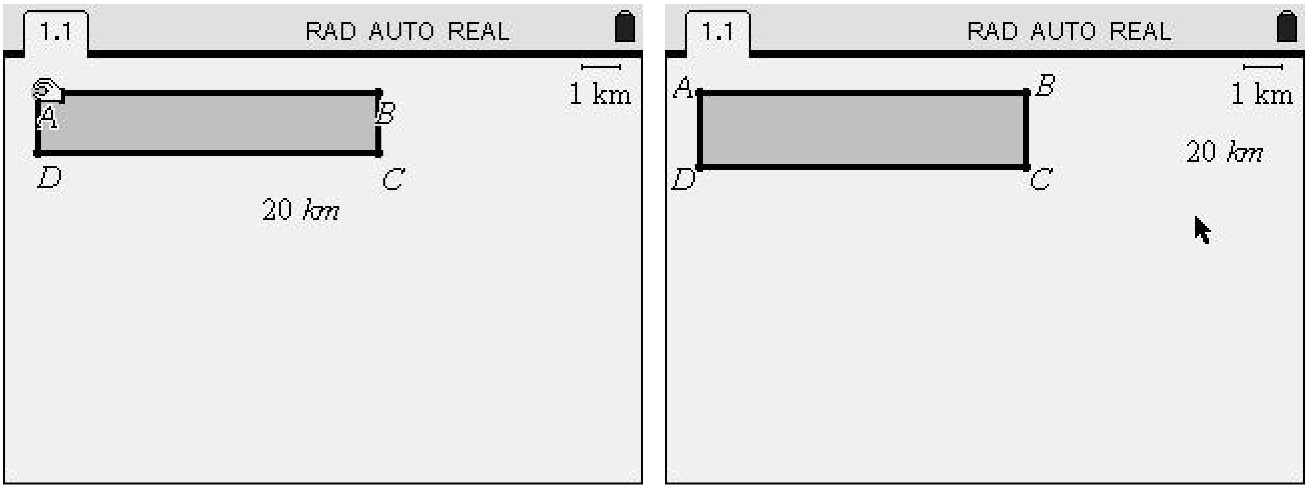




Now our construction looks much better and we can clean it up. Using the context menu we hide out the measurement of AO, the horizontal line passing by A, the segment AO and the point O, leaving nothing but the rectangle and it's perimeter.



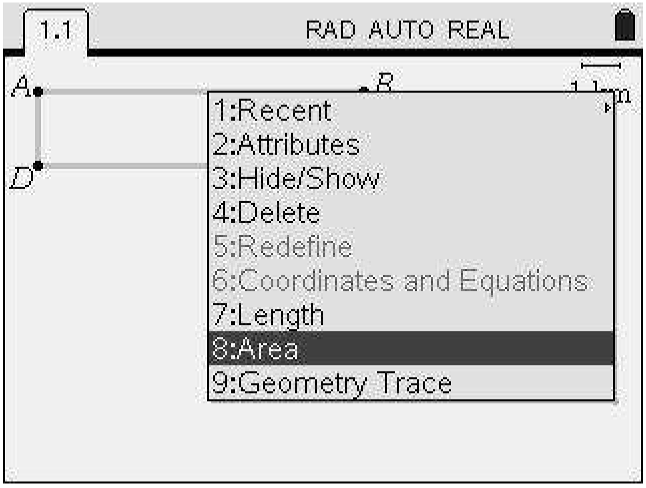
And we can carry on cleaning up the workplace: moving point A towards the upper left corner (note that the entire construction moves with point A), moving the labels A, B, C and D to improve readability (note that in this example the letter A is inside the rectangle), moving the perimeter to the right... Try to get your construction as tidy up as possible. Remember to press esc to deactivate any tools before trying to move an object. To move a label place the cursor over it and if necessary press tab until you see the message **label** pop up.

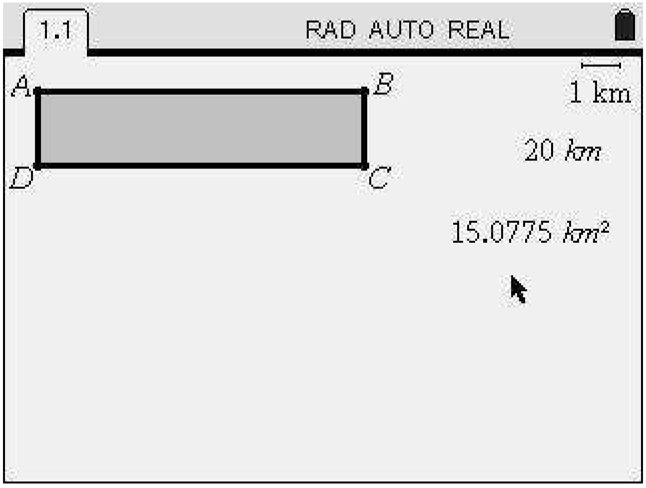


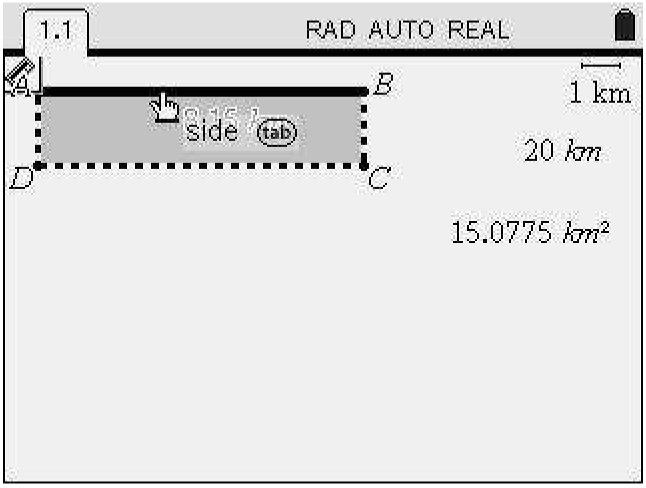
It looks much nicer now! To proceed with our investigation we now need to measure the rectangle's area and also one of the sides, for example AB. We measure the rectangle's area by using the context menu. Just move the cursor over the rectangle, press ctrl+menu and select **Area**. You'll have the area of the rectangle, in km^2, in accordance with the construction’s scale.

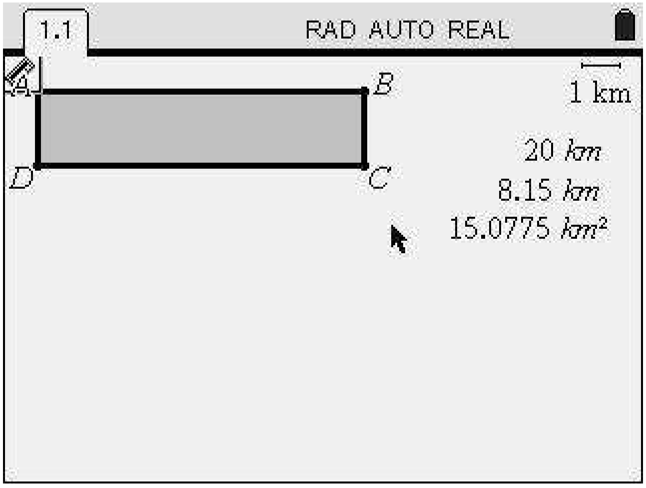
As the area is placed inside the rectangle we'll move it to the right, next to the perimeter. Place the cursor over the area, grab it and move it to the desired location.

Now measure the distance from A to B. As AB isn't a geometrical object itself, just the side of a polygon, we can't use the context menu here. So, we open the **Menu** and select **7:Measurement** and **1:Length**. We place the cursor over side AB and **polygon** will pop-up. We don't want to measure the perimeter, just the length of AB, so press tab to select the **side** and click to confirm. Now move the cursor to a desired location and click again to place the length measurement where you want it.

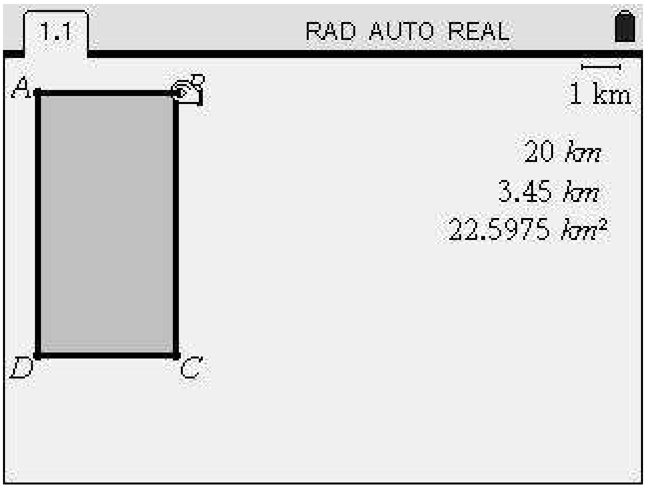


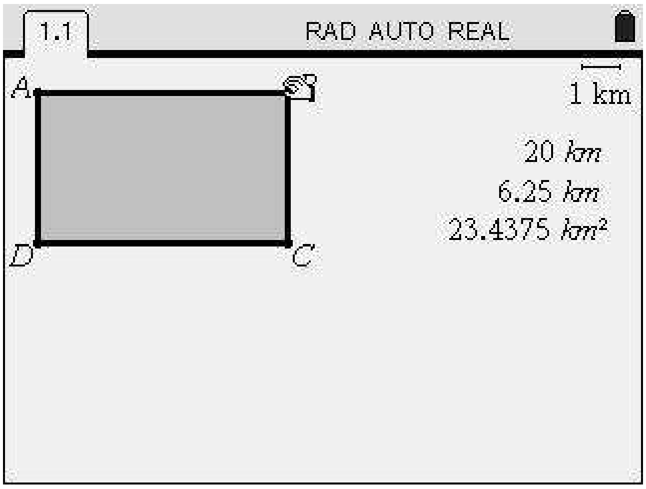






Now, just to play around, grab point B (remember to press esc before trying to grab the point) and move it around. See that both the length of AB and the area of the rectangle vary, although the perimeter stays constant, as was our objective.



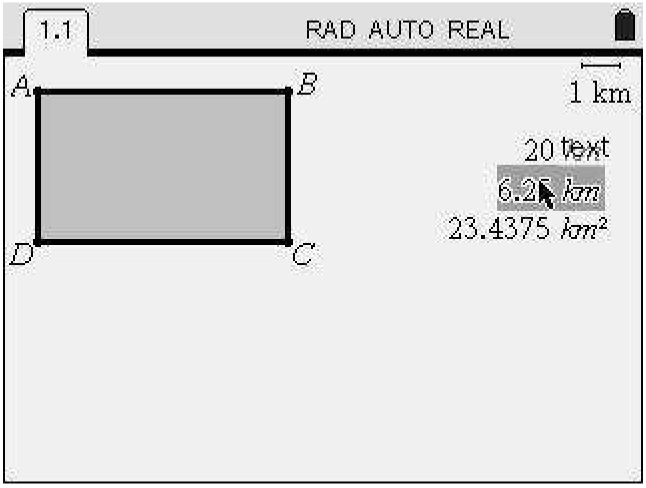


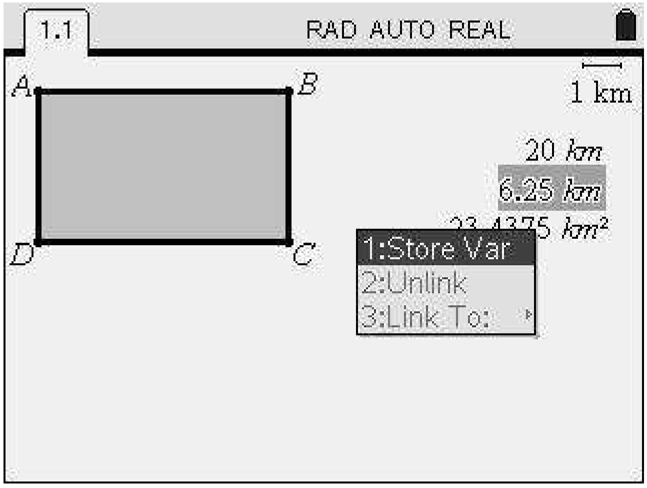
This concludes the first part of our activity, the geometrical construction. The next part is the data collection from the geometry construction and analysis of the data to determine the rectangle of maximal area.

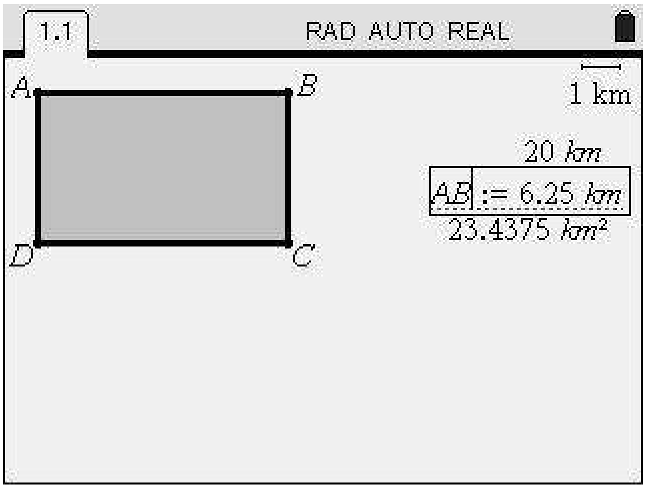
2. Data capture and analysis

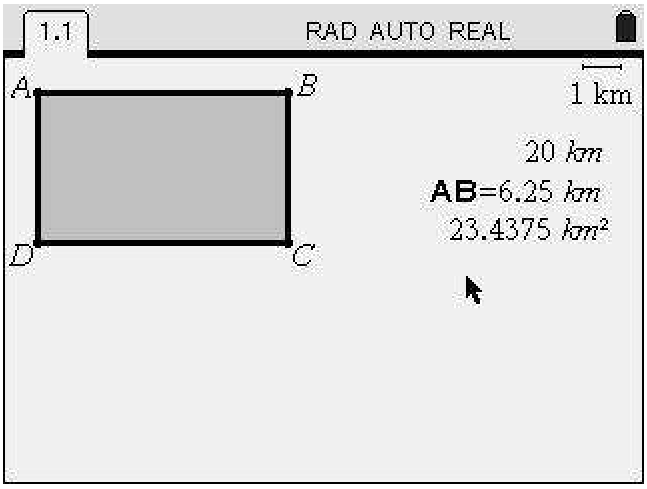
Having constructed a rectangle of fixed perimeter in the previous section we now want to keep a record of both the length of the side AB and the area of the rectangle, in order to analyze them when AB goes from 0 to 10 km.

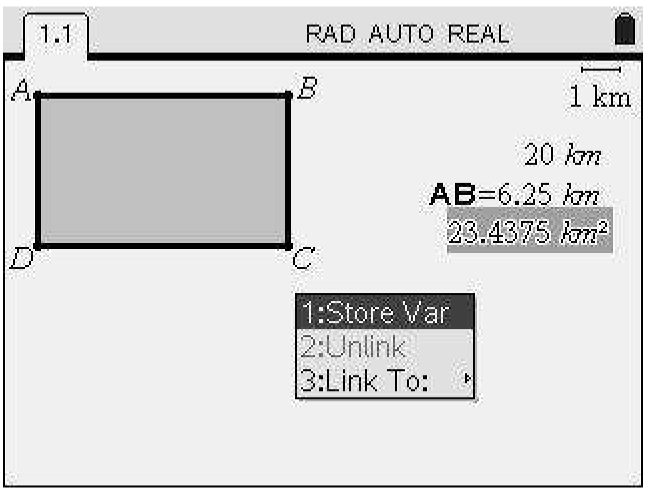
Start by clicking once over the length of AB to select it. Then press and select **Store var**. Type in a suggestive variable name (TI-Nspire allows for variables to have up to 16 characters), such as **AB**, then press to confirm. Do the same to the area measurement and store it in variable **Area**.

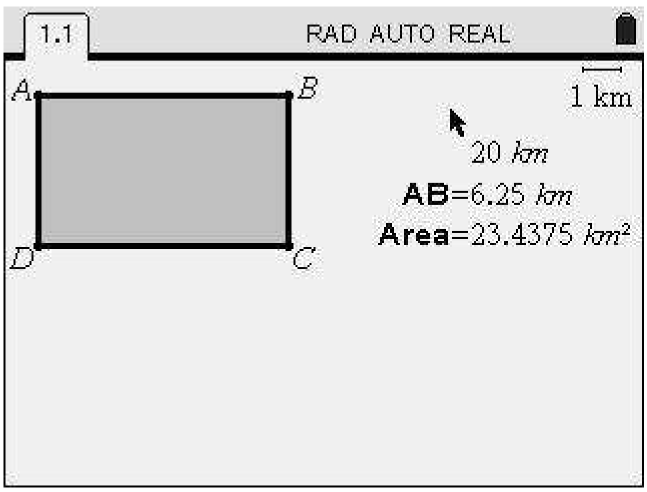




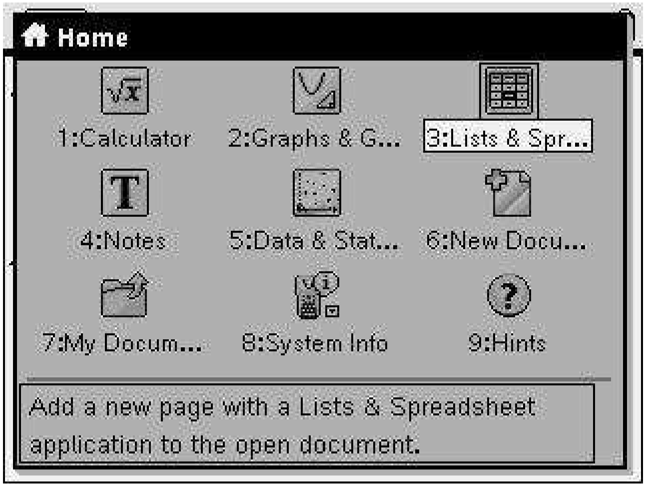


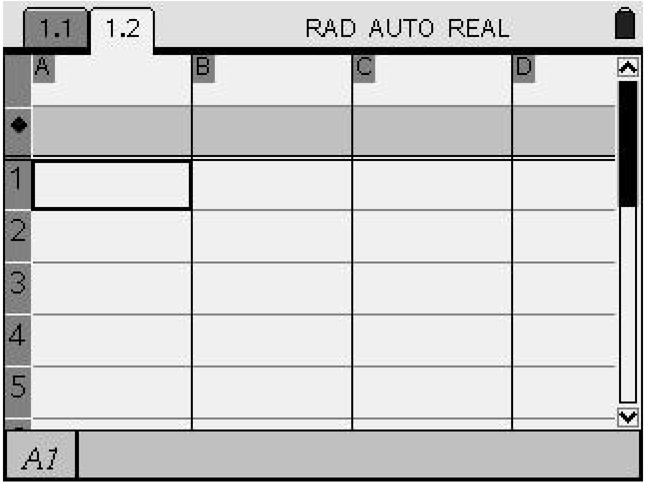




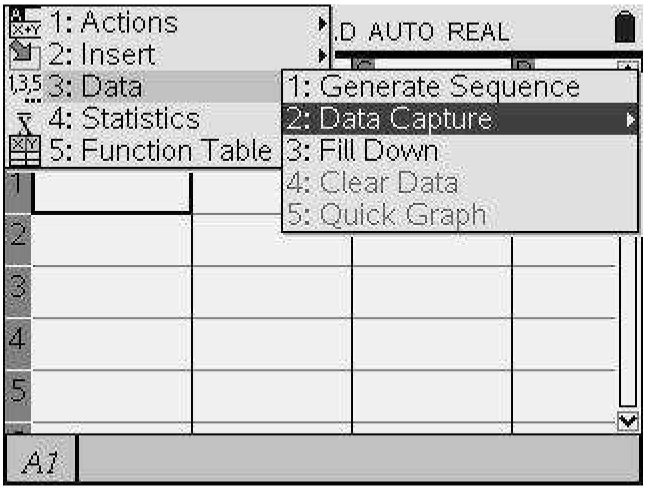


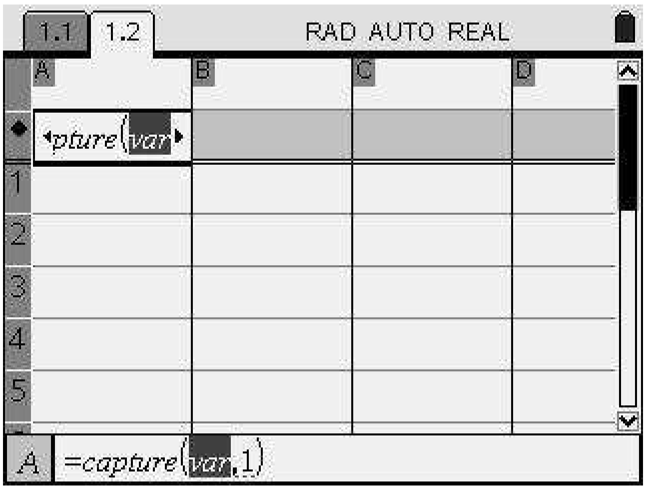
We now insert a spreadsheet page. We can do that either by opening the **Tools menu** by going to the **Home screen** or by using the shortcut ctrl+i. Here we show you how to do it using the **Home screen**.

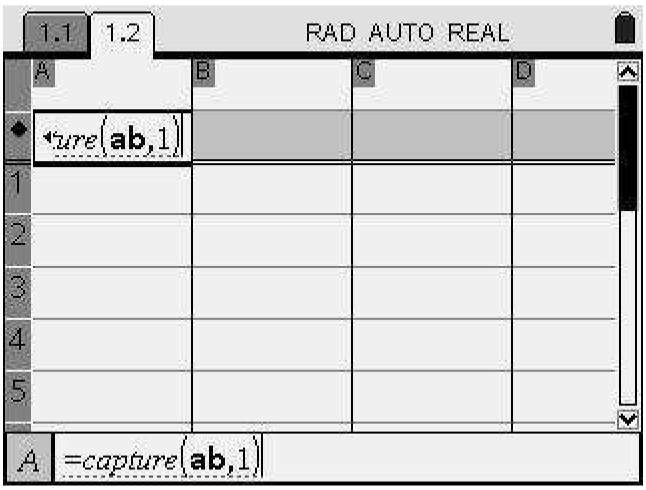


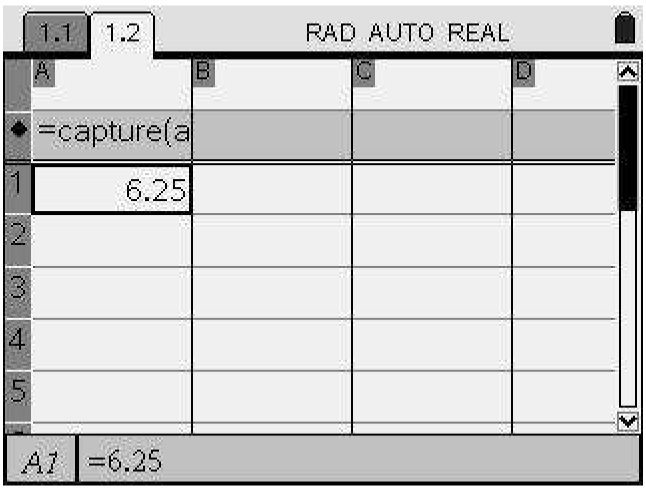


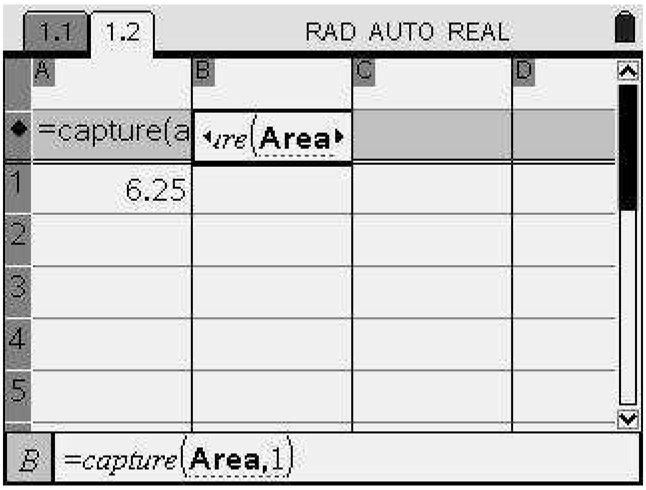
On the spreadsheet we can **Capture data** from a geometric construction: open the **Menu** and select **3:Data**, then **2:Data Capture** and finally **1:Automated Data Capture**. You can see that the editing line now reads "=capture(var,1)". Replace var by the first variable, **AB**, and press enter. The current value of **AB** is displayed in cell A1. Then do the same and set up column B to capture data stored in variable **Area**.

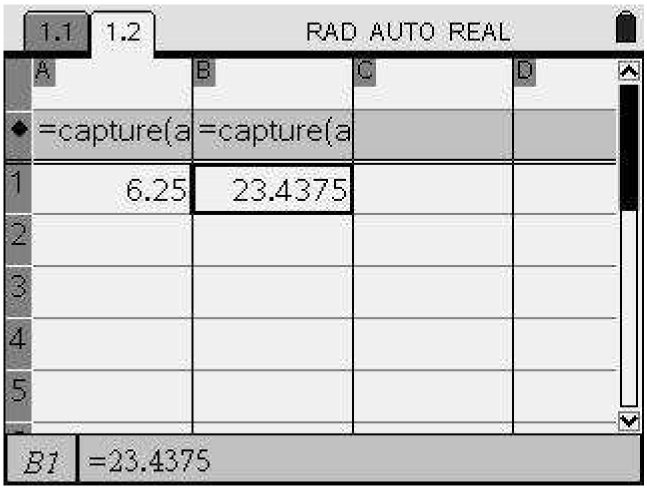




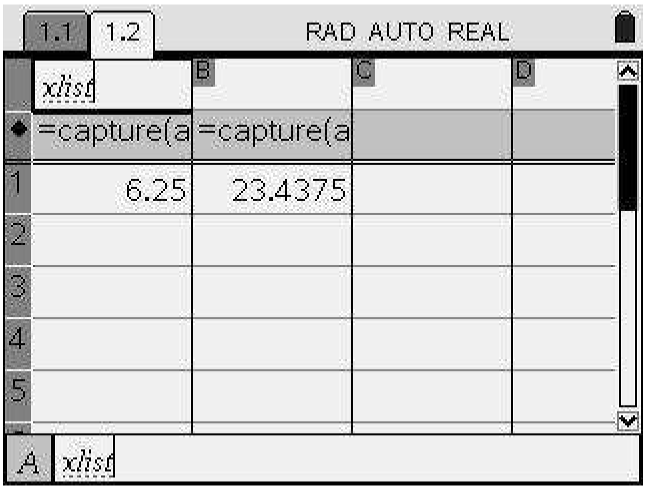


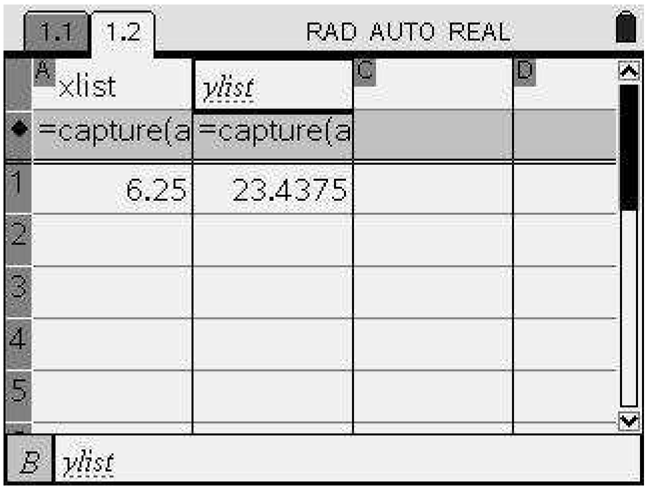




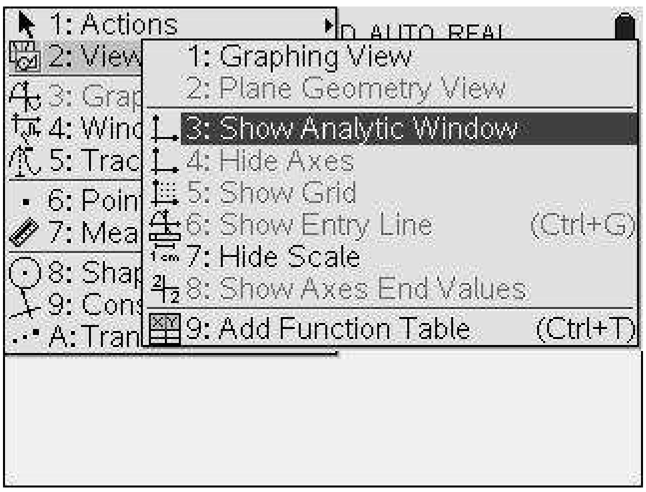


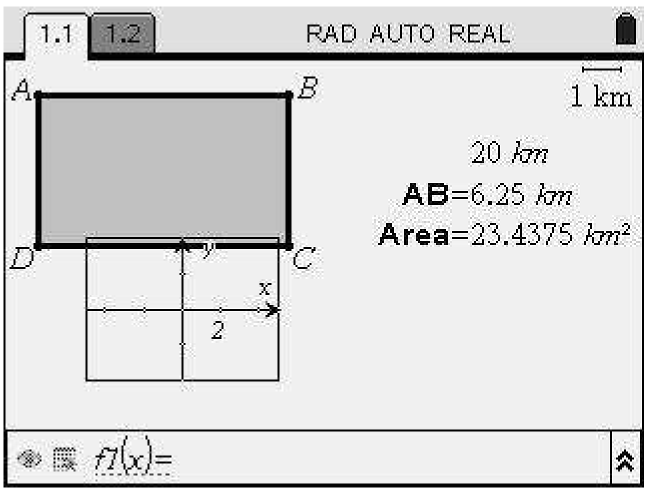
We now have both the side length and the area on the spreadsheet. Now every time we move point B the new values of **AB** and **Area** will be stored in a new line of the spreadsheet, creating a set of points that we can then plot and analyze. For that we need to give names to the columns. Place the cursor on the top row of column **A** and type in **xlist**. Do the same in column **B** and type in **ylist**.



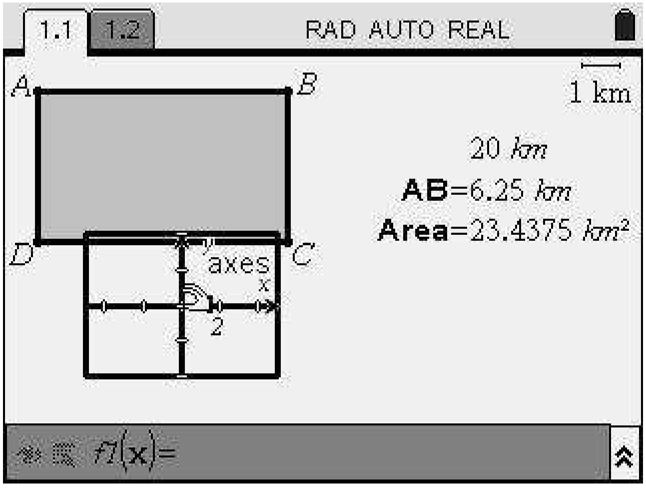


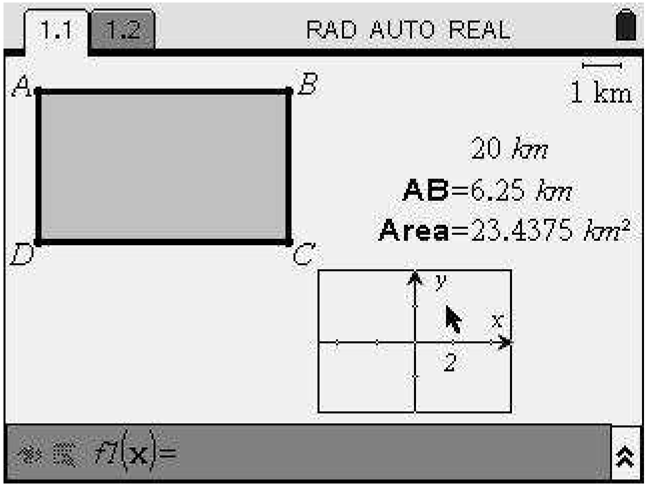
Go back to the geometry page by pressing ctrl+LEFT and add an **Analytical Window**, that is to say, a small window with a system of axis where we can plot graphics. Open the **Menu** and select **2:View** and **3: Show Analytic Window**.



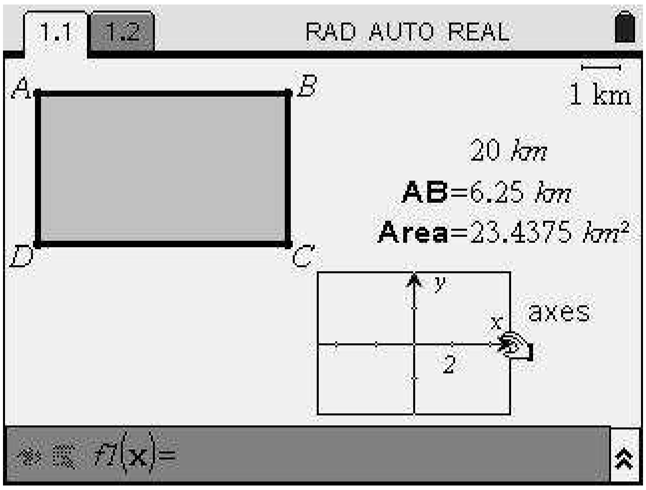


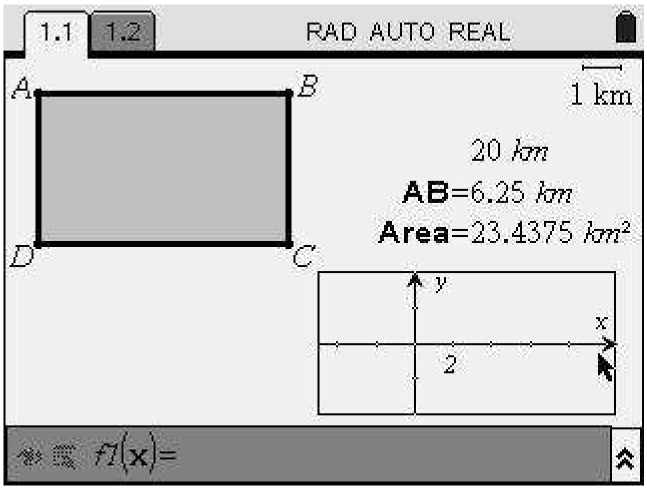
When we activate the **Analytic Window** we have an **Entry Line** at the bottom, where we can define the functions to plot or choose lists to use in a scatter plot. However, prior to define the plot it's convenient to adjust the Analytic Window's position. Leave the Entry Line by esc. You now have the cursor again on the worksheet. Move the cursor to the axis, grab them and move the Analytic Window to a more convenient location, at the right.





Also, note that this Analytic Window is rather small. So it's a good idea to extend it a bit, namely to the right. Place the cursor over the right arrow on the **x** axis until it starts to blink then grab it. Note that the pop up message must be **axes** and not **label**. Label is the *x* letter labeling the axis. Move it to the right. When it reaches the desired location release it. This can also be done with the **y** axis and also with the negative part of each axis, but we'll leave it like this.

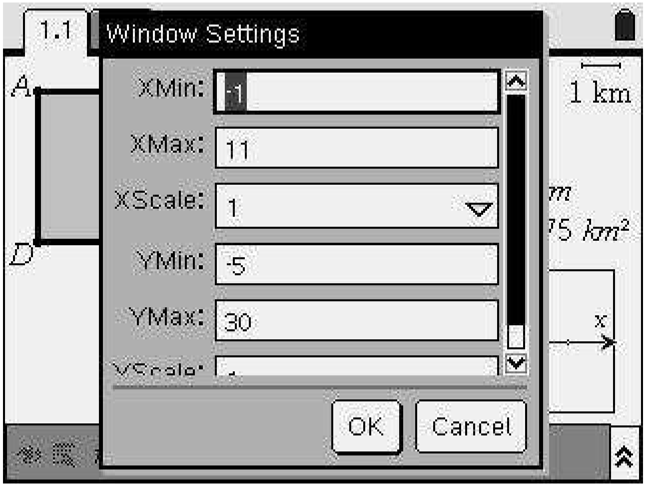


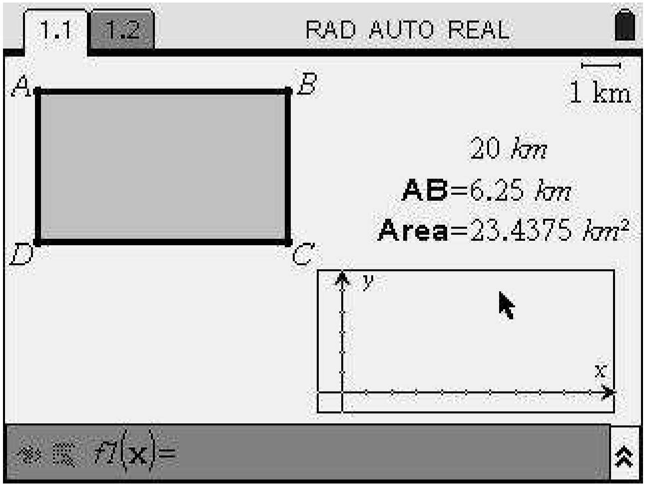


Next open the **Menu** and choose **4:Window** and **1:Window Settings**. A pop up dialog appears allowing us to define the minimum and maximum values of each axis. Set **xMin** to -1 and **xMax** to 11 and set **xScale** as 1. As for the **y** axis, define **yMin** as -5, **yMax** as 30 and **xScale** as 5.

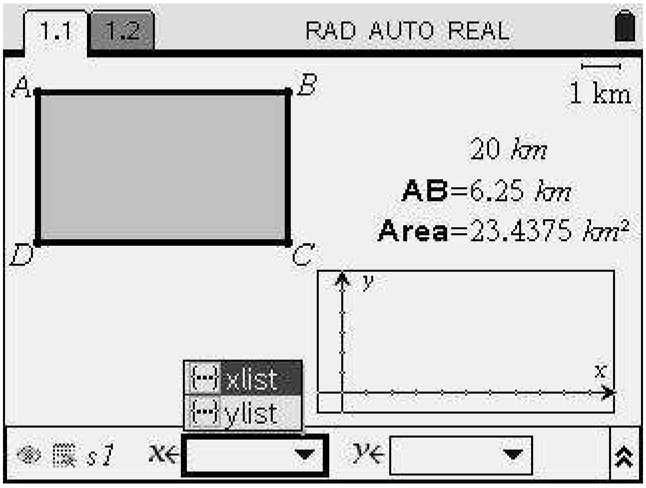
To move from one field to the next use tab. If you need to go back you can either press tab as many times as needed to return to where you want, or alternatively, press shift+tab to move back. Once all values are defined confirm your selections by moving to the **OK** button and pressing enter.

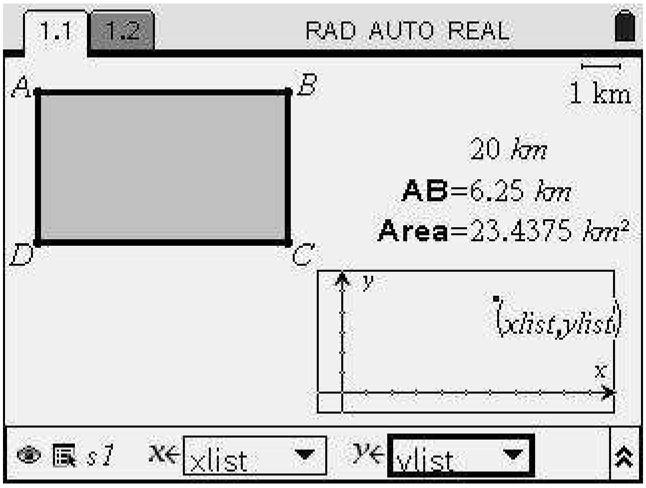
Remark: These values were chosen so that both axis are visible and all our data fits in the window. The choices for **xMin** and **xMax** are obvious, as **AB** will change between 0 and 10, but the choices for the **y** axis require that one knows what results to expect.



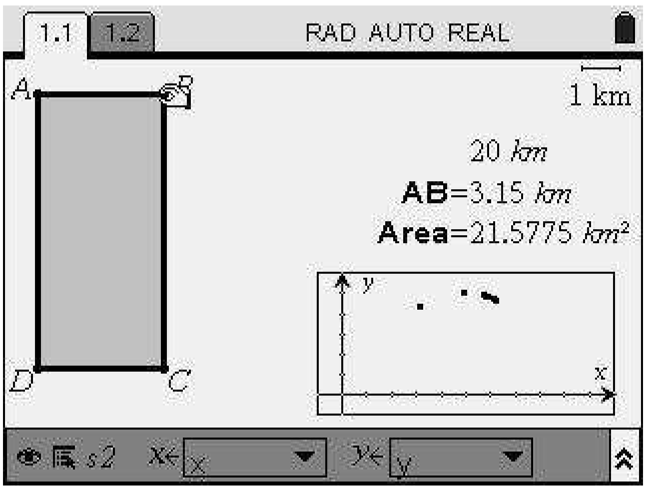


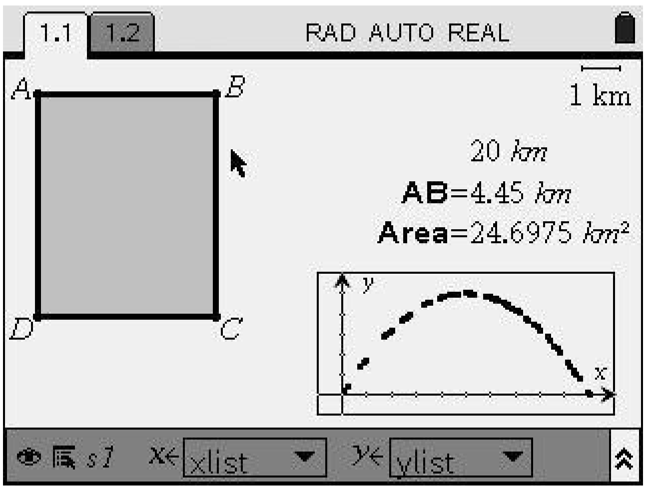
Now we set up the scatter plot, using the **x** and **y** lists defined on the spreadsheet page. To do that go to the Entry Line, either pressing tab or moving the cursor over it and clicking. Open the **Menu** and choose **3:Graph Type** and **4:Scatter Plot**. Open the selector for x and y and choose the corresponding lists, **xlist** and **ylist**. To move from the **x** selector to the **y** selector we use the left and right arrows or tab.



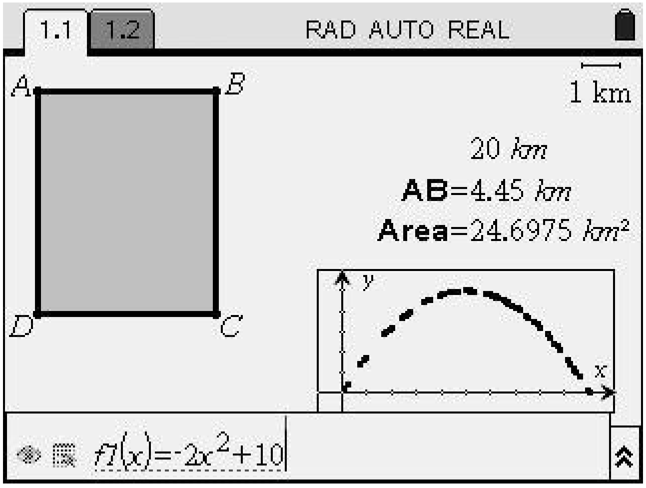


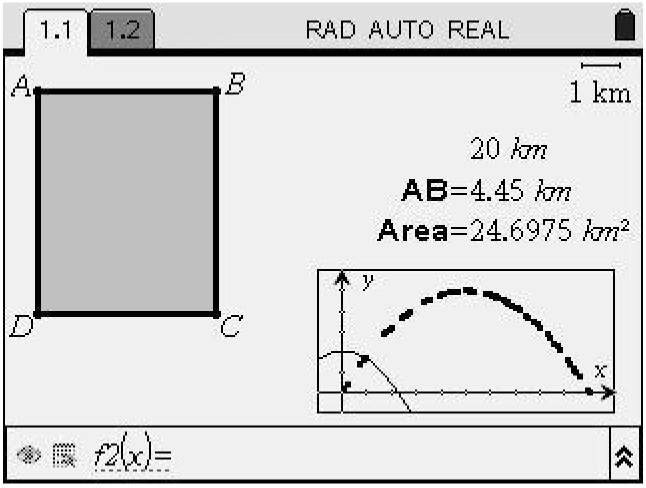
The plot appears, although it has only one point of data. We can hide the scatter plot label, to avoid getting a window with too many objects overlapping. Now, to populate our lists and plot the data at the same time, press esc to leave the Entry Line, grab point B and move it. Gather enough data to be able to make a conjecture. Namely, make AB get close to its minimum and maximum length.



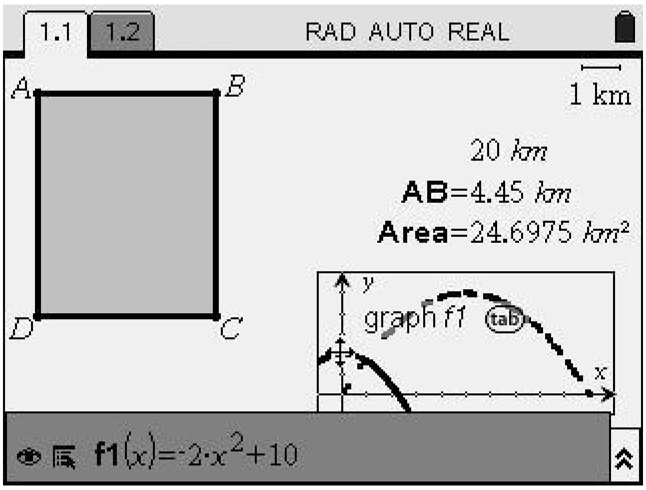


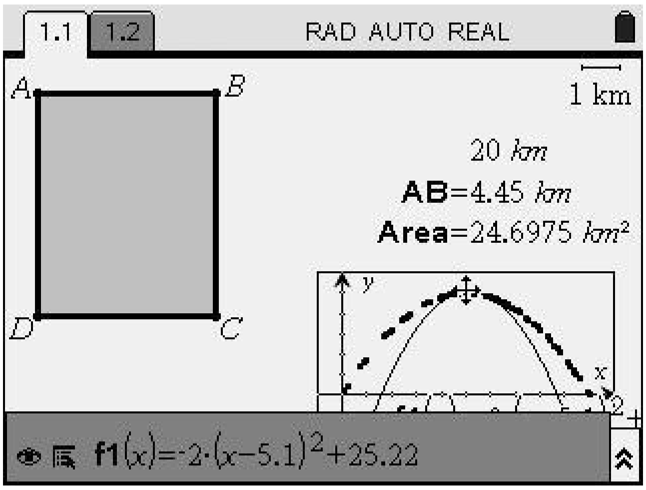
The data seems to describe a parabola. So now we plot a generic parabola and try to get it to overlap the data. From the **Menu** select **3:Graph Type** and choose **1:Function**. The Entry Line is now active and you can type in any function. Type in the formula to a parabola. Afterwards we'll try to adjust it to the points. Given that the parabola is reversed, x^2 should have a negative coefficient, for example -1. As we don't know much more about our parabola, we'll omit the first order coefficient and just add a constant, so that the parabola crosses the **x** axis. For example, we type in $f1(x)=-2x^2+10$.





As we can see the parabola we defined is nowhere near the points we've collected. So we must adjust it. Again get the cursor to the worksheet by pressing esc and place it near the vertex of the parabola, as shown below. The cursor icon changes to ✥ meaning that if we grab the parabola at this position we'll move the vertex around. So we grab it (long click or ctrl+click) and move it to get near to our data. By doing this we move the parabola and the defining expression also changes accordingly.

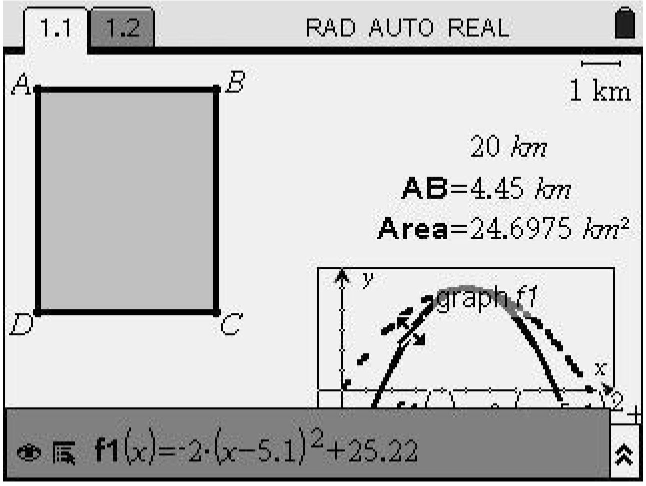


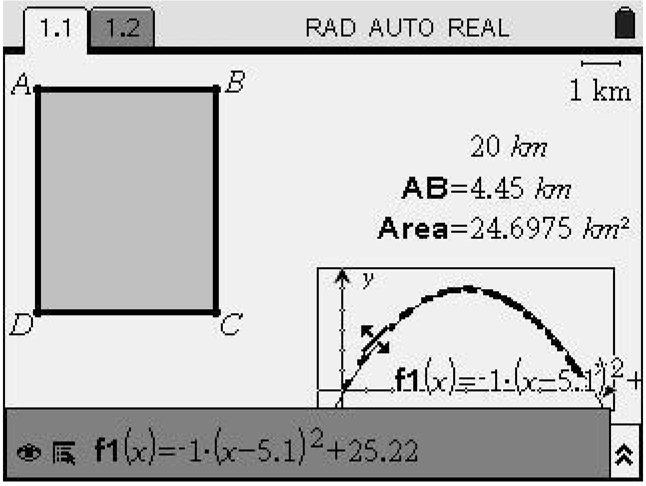


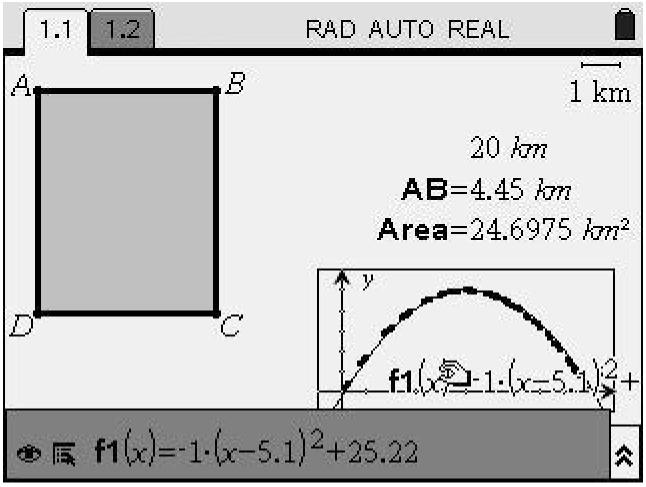
After adjusting the position of the vertex we can bend the parabola's arms, to increase or decrease the curvature. Move the cursor to one of the parabola's arms until the cursor changes to ⤡. Adjust the arms of the parabola so that the curve overlaps the points of data as perfectly as you can.

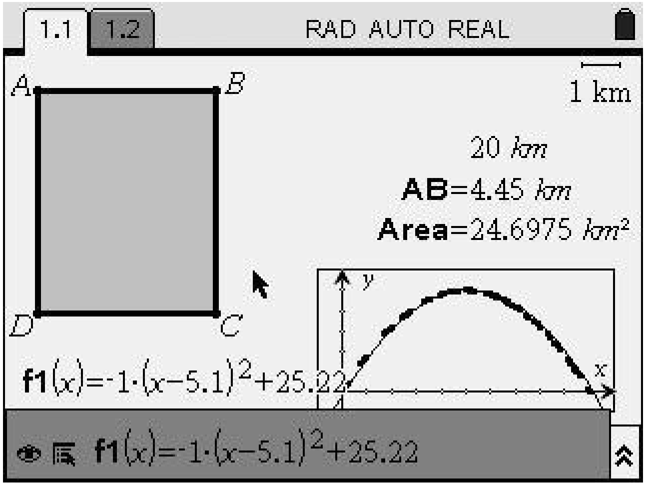
Note the difference between this icon and the previous one, ✥. One means that only the curvature is changed, the other means that the vertex will move, leaving the curvature unchanged.

After this we can move the curve's label to somewhere more suitable. Namely, to the left of the screen, where we still have some room available. We can see that the expression of the parabola changed in accordance with our manipulation.









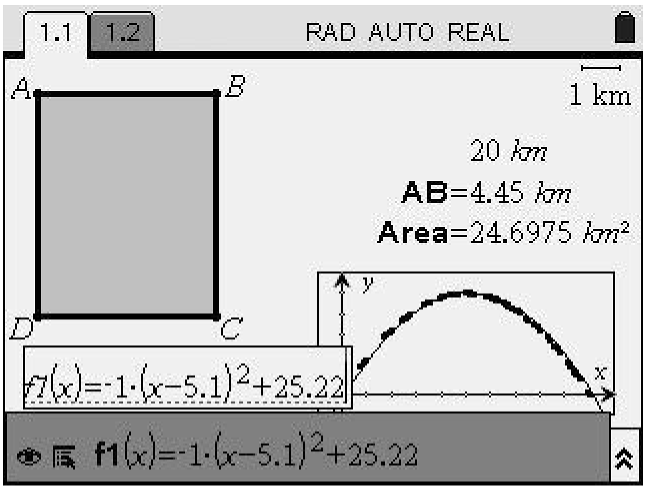
As we can see the expression is displayed as

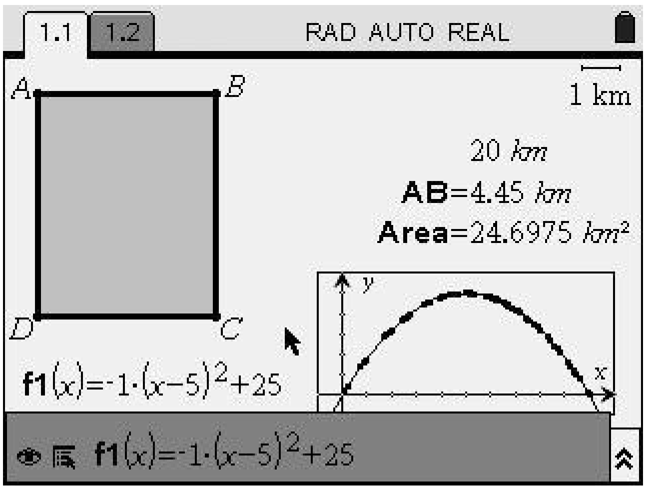
$$a \cdot (x-b)^2+c,$$

where b and c are the coordinates of the vertex. Of course a curve adjusted like this won't fit our data perfectly, but the best fit will be somewhat close to this. In this example the **x** coordinate of the vertex is 5.1. We can then make the following conjecture: the area is maximal when **AB**=5 km. In this case ABCD will be a square and the area will therefore be 25 km^2. Let’s test this conjecture by editing the expression for *f1*. Place the cursor over the expression and double click it to edit. Replace it by

$$f1(x) = -(x-5)^2+25$$

and press [enter] to confirm.



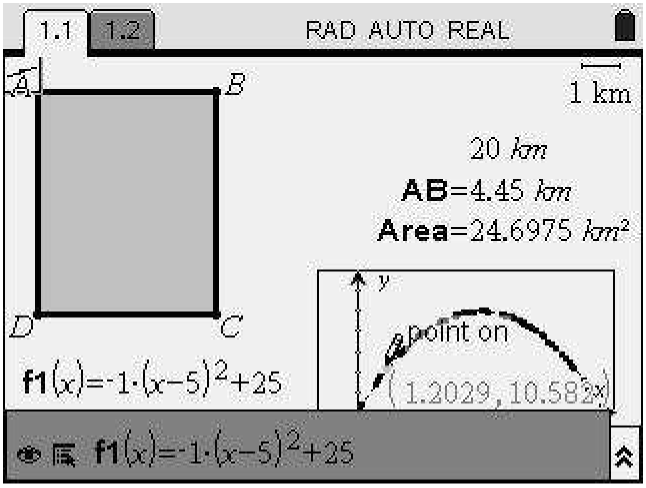


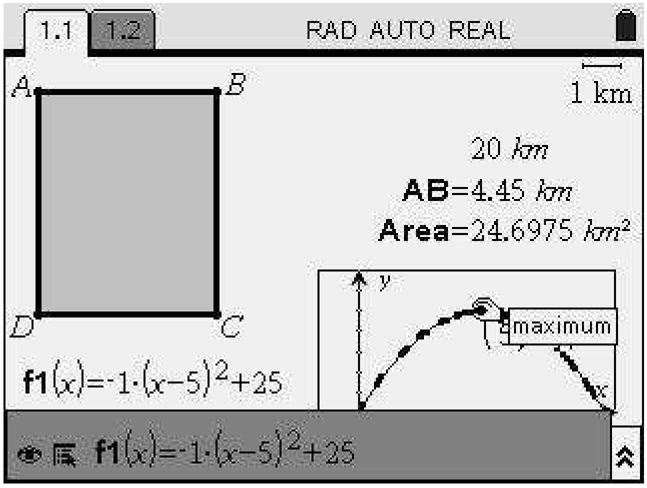
Given the results collected so far we can, with some certainty, say that the area of the rectangle is given by

$$Area = -(x-5)^2+25,$$

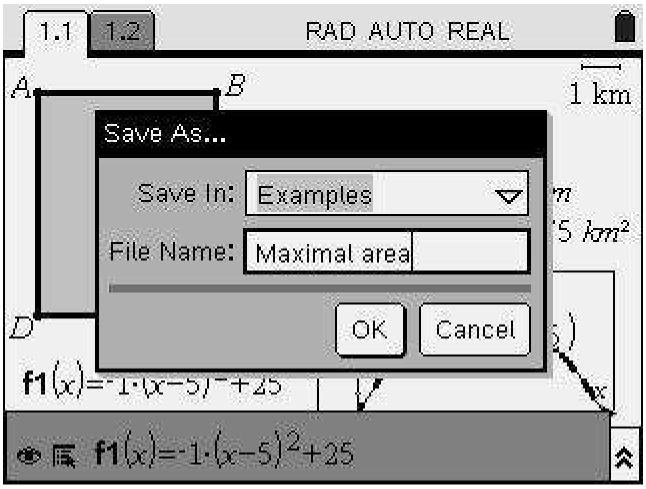
where x is the length of **AB**. So it reaches a maximum when **AB** measures 5 km, that is to say, when ABCD is a square, and in this case the area will be 25 km^2.

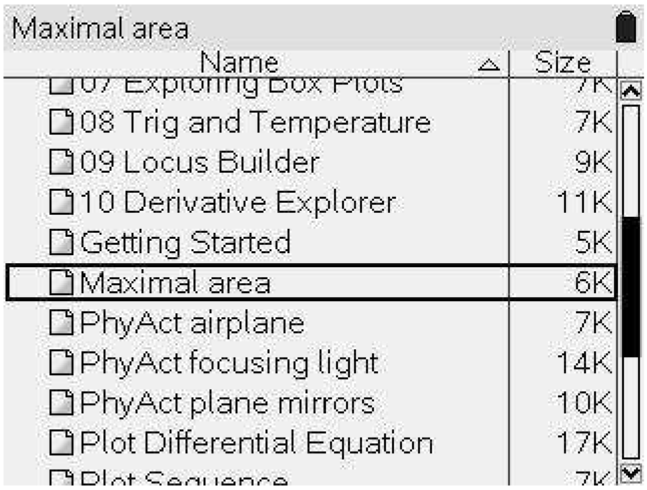
Let's, confirm that a maximum actually occurs when **x**=5 km. For that we construct a point over the graph, selecting **6:Points & Lines, 2:Point on** from the **Menu** and placing it over the function. Press esc to deactivate the tool and grab the point. Now move it towards the maximum of the function. You'll see **maximum** as a pop up message and when you release the point you can see that the maximum is reached when **AB**=5 km and that the maximal area is 25 km^2.





We can now conclude our investigation, and save the document with our work, by pressing ctrl+s or selecting **1:File**, **4:Save As...** from the **Tools menu**. Select a folder and give the document a name. Then you can transfer the file it to a computer or another TI-Nspire unit!





This concludes our activity. Many other investigations could be done and the procedures illustrated are not, by all means, the only possible route to reach the same conclusion. TI-Nspire has an impressive set of features that make it an ideal tool to teach and learn mathematics and allow teachers to adapt the activities to fit their students' intuition of to emphasize a particular aspect of the construction.

The End. May you have many Nspired mathematical experiences!