**Introduction**

The DME (Digital Mathematics Environment) is a web based learning environment, designed for the subject mathematics. It offers schools the possibility to offer students part of the mathematics subject matter digitally. The work of the students will be stored on a central server and turn the DME into a kind of digital workbook. Teachers can see student work in a score overview, but also per student on a detailed level.

- The Edit feature gives the teacher the opportunity to design activities himself. This may be done by changing existing activities, but it is also possible to design entirely new activities.

While creating activities in the DME, different type of basic components (basis widgets) can be used. The choice for a specific basic widget depends on the type of assignment; for example adding fractions, solving an equation, or choosing between some possible answers. Each basic widget offers its own possibilities to assess the answer that is entered in the answer box and giving feedback. In this *Manual Designing part 2* various basic widgets and their features are described.

**Other Manuals**

*Manual Designing Part 1* shows the starting designer several basic possibilities that the DME environment offers. The idea is to follow the examples that are explained step by step, in order to become familiar with changing and creating activities.

In *Manual Designing Part 3* is explained how entirely new activities can be designed, using the more advanced features of the DME.

On [www.dwo.nl/en/teacher](http://www.dwo.nl/en/teacher), as addition to the manuals, you can find detailed explanations and examples of several widgets:

### File Edit

- DME Math Environment
  - DME Widget list
    - Algebra widgets
    - Basic widgets
    - Geometry widgets
    - Other widgets
    - Statistics and probability widgets

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1. Basic widgets

To insert a basic widget on a page, place the cursor right there where you want to have the basic widget and click on the white rectangle in the menu bar. In the pop-up that appears, you can choose the basic widget.

2. Formula answer box with steps

An important and large group of mathematical tasks has an expression as answer. Some examples:

- Perform this calculation
- Factorize this formula
- Calculate the function value for a certain value of x
- Simplify to one fraction
- Set up a formula for the volume as function of the diameter
- Give the derivative of a certain function

The DME offers feedback on the correctness of a given answer. To be able to do so, the software needs to ‘understand’ the ‘meaning’ of the expressions. Then it can check equivalence with the correct answer. As the DME is able to understand expressions, all steps towards the final answer can be checked. This means that students can receive intermediate feedback when they are performing a strategy to find the final answer.

In the DME, the student is free to choose his/her own strategy. Especially this stepwise feedback on an own strategy has proven to be powerful, and therefore played a central role in designing the DME software. In this chapter, the use of these feedback features will be clarified.

First make a new activity using the Template Expressions Step-by-step (for more information about the use of templates, see Manual Designing part 1) or make an answer box with and choose Formula answer box with steps.

In the left hand column, fill in the title of the task and the task itself. Use the formula to fill in the given expression.
Now click on the box in the right hand column and a pop up with the answer box editor appears:

Click \(\text{OK}\) and next to see the task the way the student will see it. When solving this task, every step will be checked after the student has pressed the Enter button. If a student’s step is equivalent to the final answer, but not yet exactly the same, an orange tick mark \(\checkmark\) appears as feedback:

\[
(a + 3)(a - 5) - 2a =
\]

\[
a^2 - 5a + 3a - 15 - 2a =
\]

\[
\checkmark
\]

If the answer is exactly the same as the answer model, a green tick mark \(\sqrt{\text{ }}\) appears.
Using a prefix
When a student is asked to give a formula (or numerical expression), for example a derivative, a prefix is often required. For example, $f'(x) = 18x + 60$ would be preferred over $18x + 60$.
This can be ‘enforced’ by adding the prefix to the answer model:

In this example the prefix $f'(x) =$ is already offered to the student:

Now the student can work towards the answer step by step, and receives feedback on every step:
3. Equation answer box with steps

Another category of mathematical tasks consists of equations that have to be solved. For these tasks, stepwise feedback is again a powerful feature. After all, the steps towards the final answer are all equivalent equations (that, if everything goes well, get less and less complicated). Because this equivalence can be checked, feedback can be provided on the steps the student does.

We will first give an example.

The equation in the left hand column is made using the formula editor. This formula can be selected with the cursor, and then be copied and pasted as starting equation in the answer box. To open the answer box editor, just click the answer box. Copying and pasting this way is easier than retyping the equation.

Now click the button ‘possible answer’ and the correct solution appears.

Copy this solution. Close the pop up (click the square in the top right corner) and paste the solution into the answer model. Of course, you can also calculate the solutions yourself.

When a student now works on this task, every step will be checked after pressing Enter. If a step is equivalent to the final solution, but not yet exactly the same, the orange tick mark \( \checkmark \) appears. If the given answer is exactly the same as the answer model, the green tick mark \( \checkmark \) appears:
Feedback (built-in)

Every equivalent equation can be used as intermediate step. This offers the student the freedom to find his/her own way to the solution. Because of the feedback, the student knows that he is (still) on the right track. The equivalence is checked by substituting the solutions from the answer model into the student’s equation. For solving equations, the software can even give some more detailed feedback for some common errors. Some examples:

\[ x^3 + 4x = 5x^2 \]

\[ x^3 - 5x^2 + 4x = 0 \]

\[ x^2 - 5x + 4 = 0 \quad \text{or} \quad x = 0 \]

\[ x = 4 \quad \text{or} \quad x = -1 \quad \text{or} \quad x = 0 \]

These are built-in feedback options, so they will automatically be added to the activity.
Feedback (built-in), intermediate and final answers

For some types of equations the intermediate steps are not always equivalent. For example in equations containing square roots, often both sides are squared, which might introduce extra solutions which later have to be rejected. But for intermediate steps, these solutions should be accepted.

\[ \sqrt{x + 3} = 3 - x \]

\[ x + 3 = (3 - x)^2 \]

\[ x^2 - 6x + 9 - x + 3 \]

\[ x^2 - 7x + 6 = 0 \]

\[ (x - 1)(x - 6) = 0 \]

\[ x - 1 = 0 \text{ or } x - 6 = 0 \]

\[ x = 1 \text{ or } x = 6 \]

Only in the final step the student receives the feedback that a little more work has to be done. In the editor, the answer model is built as follows:
Actually the author gives two solutions, separated by the semicolon. The first solution suffices as intermediate solution, but not as final solution. For the final solution, the second given solution is required. This approach can also be useful for fractional equations.

Feedback (built-in), rounding off solutions
It often happens that students have to round off final solutions. Stating these rounded solutions as our final answer would lead to trouble with the intermediate steps, as these rounded answers cannot be used to check the intermediate solutions. This problem can also be solved by inserting both intermediate solutions and final solutions.

Now the intermediate steps can be done without any problems. If the student does not round the final answer off by himself/herself, feedback will remind him/her to do so. (The system cannot handle intermediate rounding off.)

\[ x^2 - 3 = 0 \]
\[ x^2 = 3 \]
\[ x = \sqrt{3} \quad \text{or} \quad x = -\sqrt{3} \]
\[ x \approx 1.73 \text{ or } x \approx -1.73 \]
No solution

If an equation does not have any solutions, the following answer model can be used:

Now the student can fill in: ‘no solutions’ and that solves the equation correctly:

\[ x^2 + 3 = 0 \]

\[ \text{no solutions} \]

However, often the student will first have to make some intermediate steps, before he/she can conclude that the equation does not have any solutions. This is problematic, as there is no solution to check the equivalence with.

There are two solutions to this problem.

- The first solution only works for quadratic equations.
  As ‘intermediate solution’ the coefficients of the equation are given:

| 1 : 0 : 3 |
| \[ x = \text{no solution} \] |

Now it is possible to do intermediate steps.
A solution which also works for other types of equations is the use of complex numbers. The complex solutions are given as intermediate solution:

$$x^2 + 3 = 0$$

$$x^2 = -3$$

$$x = i\sqrt{3} \text{ or } x = -i\sqrt{3}; \quad x = \text{none}$$

**Equation answer box with steps: Operation buttons**

In equation answer boxes with steps, the designer can offer the student several tools for solving equations. Often the goal is to practice finding suitable steps to solve the problem. With these options, it is possible to focus on this goal. The new equation will be calculated for the student.

To add these, select **Operation buttons**:

- Strategy version
- Strategy+ version
- Cover-up method version
- Arrow
- Operation buttons
- expand
- Operation buttons extra

These buttons offer the students the possibility to perform operations on the equations. After choosing an operation (and possibly filling in a number), the student should press Enter. Then the new equation will be automatically calculated and filled in.

Several buttons are available $\pm \times \div \sqrt{\text{N}}$.

For example to expand brackets:

$$(x + 3)^2 + x = 9$$

$\checkmark \quad x^2 + 6x + 9 + x = 9$$
To simplify:

\[(x + 3)^2 + x = 9\]
\[x^2 + 6x + 9 + x = 9\]
\[x^2 + 7x + 9 = 9\]
\[\checkmark x^2 + 7x = 0\]

To subtract the same number from both sides:

\[(x + 3)^2 + x = 9\]
\[x^2 + 6x + 9 + x = 9\]
\[x^2 + 7x + 9 = 9\]
\[\checkmark x^2 + 7x = 0\]

From here the student has to finish the solution by him/herself.
(See also Operation buttons extra)

**Discr-button**

This button offers the student the possibility to calculate and check the discriminant. For example:
**Substitution-button**

Select substitutions:

- Strategy version
- Strategy+ version
- Cover-up method version
- Arrow
- Box
- Operation buttons
- discr
- subst.
- Operation buttons extra
- subst. exten.

This button creates the possibility to use a substitution, for example to solve equations containing higher powers of x:

\[x^4 - 4x^2 + 3 = 0\]
\[p^2 - 4p + 3 = 0\]
\[(p - 1)(p - 3) = 0\]
\[x^2 = 1 \text{ or } x^2 = 3\]

**Operation buttons extra**

Select Operation buttons extra:

- Strategy version
- Strategy+ version
- Cover-up method version
- Arrow
- Box
- Operation buttons
- discr
- subst.
- Operation buttons extra

This offers the student some more operations to perform on equations. Three more buttons are added to the bar with operation buttons. Again the Enter button should be used after selecting an operation button; the new equation will be automatically calculated and filled in.
Factorize:

\[ x^3 = 3x \]
\[ x^3 - 3x = 0 \]
\[ x(x^2 - 3) = 0 \]

If this option is selected, students are forced to choose one of the operation buttons, as no empty line appears to type in a new equation manually. The operation buttons will be shown automatically.

Split:

\[ x^3 = 3x \]
\[ x^3 - 3x = 0 \]
\[ x(x^2 - 3) = 0 \]
\[ x = 0 \text{ or } x^2 - 3 = 0 \]

The difference between this option and the previous one is that, after choosing an operation, the student gets an empty line in which he/she should fill in the next step him/herself.

Strategy version

- [ ] Strategy version
- [ ] Strategy+ version
- [ ] Cover-up method version

Strategy+ version

The equation is solved correctly.
Cover up strategy

With this option, students can practice using the cover up strategy. Select a part of the equation with the cursor, then let go of the mouse button. The selected part will appear on the next line. This part can be used to create an equivalent equation, etc.

The designer can combine the cover up strategy with operation buttons, to offer the student the possibility to choose and switch between different strategies. An example is shown at right.
Inequalities

Linear inequalities can be solved in the same way as regular equations. Inequality signs can be used in the answer model, and in the steps used by the student. The ≥ and ≤ signs can be obtained by typing >= and <= respectively.

The ≥ and ≤ signs can be obtained by typing >= and <= respectively.

Quadratic and other non-linear inequalities are hardly ever solved directly. First the corresponding equation is solved. Then (often graphically) the solution for the inequality is determined. (See manual part 4: Graphs)

Again, the difference between intermediate solutions and final answers is used in the editor.

With these settings, the student will automatically receive feedback when the final solution to the inequality is not given yet.
Problem 2

Solve algebraically:

\[ x^2 - 6x + 5 < 0 \]

First find the solutions of the equation and next give the solutions for the inequality.

\[ (x - 1)(x - 5) = 0 \]

\[ x = 1 \quad \text{or} \quad x = 5 \]

The inequality is solved correctly.

\[ 1 < x < 5 \]
4. Multiple choice answer box

The choice answer box can be used to create simple multiple choice tasks, like the one shown here. After selecting the multiple choices answering box, indicate the number of choices the student can choose from and press enter. Then a number of textboxes will appear, in which you can fill in the answers from which the student should select the correct one. Retype the correct answer in the ‘answer model’ text box and fill in a score to complete the assignment.

For example:

The student sees:

How many different real solutions does the equation \( x^2 - 2x + 1 = 0 \) have?

Choose

0
1
2
3
5. Check selection Unit

The possibilities of the multiple choice answer box are limited. It’s not possible to have more than one correct answer and the answers will always be given in the same order. An answering box which gives more possibilities is the check unit answer box. With this answer box tasks can be designed in which students select one or more correct objects (with numbers, formulas, pictures, ..) from a collection of objects by clicking them.

Example 1: Multiple selections possible

A task like the above can be created in the following way:

- First the selection objects are created. These are always text boxes, so insert a text box first.
- At least select the following option:
  - Selection object
  - Other settings are the designer’s own choice.
- In the text box editor, each object should be given an ID.
  - The first object gets ID = 1, the second ID = 2 etc.
The first object in the example is created with the settings shown below:

- You can also select ‘Floating above text’, to be able to put the selection objects in any position you like. After clicking OK, you will see both a small circle, and the floating text box:

To move the text box, click the top left corner, keep the mouse pressed and drag the text box to the desired position. When dragging, the open circle will be colored black, as indication that it belongs to the text box that is being dragged. This is especially relevant if you would like to copy or delete the floating text box; that can be done by selecting the small circle and copying or deleting it.

- Only after all the objects have been created, the CheckUnit is added. Make sure the cursor is placed after the circles corresponding to the text boxes.
In the CheckUnit editor, fill in the number of objects and press Enter. A list with ‘Number of selection objects’ will appear. Here you can select the correct one(s). If more than one answer is correct, also select ‘Multiple selections possible’. The positions of the selection objects can be randomized, if desired.

Example 2: Check selection with a formula

Problem 1
Color $\frac{3}{10}$ part of the rectangle.
Click a box to color it. Click it again to remove the color.

For the task above, 20 selection objects have been created.

Each object has its own ID, and value 1.
The formula is

\[ V_1 + V_2 + V_3 + \ldots + V_{14} + V_{20} = 0 \]
6. Check drag/drop unit

Example 1: Check on fixed targets for drag objects

- First, the drag targets are created. Again, these are text boxes. At least select the following options:
  - Floating above text
  - Drag target
  - Other settings are the designer’s own choice.
- In the text box editor, each object should be given an ID. The first object gets ID = -1, the second ID = -2 etc.

The first target of the example above has the following settings:
• After the targets, the drag objects are created. Make sure that in the text, their anchor points (circles) are placed after the anchor points of the target objects. Insert a text box and at least select the following options:
  - Floating above text
  - Drag object

Other settings are the designer’s own choice.

• In the text box editor, each object should be given an ID. The first object gets ID = 1, the second ID = 2 etc. This has to be done in such a way that object 1 corresponds to the target with ID -1, etc.

• When all objects are created, the Check drag/drop unit is added. Make sure the cursor is placed after the drag objects and targets objects.

• Fill in the number of drag objects and the number of target objects. It is possible to have more objects than targets or vice versa. Select ‘Check on fixed targets for drag objects’.

• ‘Snap to target’ is an option you may or may not want to select, depending on the design. If this option is selected, you can also indicate the accuracy with which the student should place the drag object. The larger the number you fill in for ‘Snap margin’ the easier it is for the student to put a drag object on a drag target. If desired, the positions of the drag objects and targets can be randomized.
Example 2: Check using values of drag objects

In this example (in Dutch) the product of the two drag objects in each line should be 18:

The design is very similar as for the Check drag/drop unit using fixed targets. The difference is:
- The drag objects each get a value. In the example the drag objects get the same value that is shown on these objects:
In the Check drag unit’s editor the option ‘Check using values of drag objects’ is selected. In the window that appears, rules for checking the answer are given:

\[ V_1 \cdot V_2 = 18 \]

Example 3: Check using values of drag objects
Manual Designing Part 2 Basic widgets  

\[ y = x^2 - 4x + 4 \]

**Checkable**  
Number of drag objects: 6  
Number of target objects: 4  
Target object as collection area: [ ]

Score: 10  
Randomize positions: [ ]  
Snap to target object: [ ]  
Jumps back: [ ]  
Snap margin: 20

Check on fixed targets for drag objects: [ ]  
Check using values of drag objects: [ ]

\[ V_1 = (x - 3)^2 \]
\[ V_2 = (x + 2)^2 \]
\[ V_3 = k(x - 2) \]
\[ V_4 = k(x + 2) \]
Example 4: Target object as collection area

In the example above, there is a large collection of drag objects, but there is only one target. Each drag object gets its own ID and the value that is also shown on the object:
In the Check drag/drop unit’s editor, the options ‘Target object as collection area’ and ‘Check using values of drag objects’ are selected:

\[ F(x, y) = 2x^2 + 3y^2 + 6x + 4y + 3 \]
7. Check value unit

Example: Check coherence

This answer box can for example be used for an ‘open’ multiplication table. This is what the student sees:

And this is the feedback a student receives:

In the authoring tool, the task looks like this:

There are five text boxes, each with a simple formula answer box in it. In each of these answer boxes, the option Check is not selected.
The text boxes have ID's 1 to 5.

As the order of the different columns is not important, only the coherence in the different columns is checked.

The answer box editor looks as follows:

In the first line, ";4" is added after the formula. This 4 indicates that the feedback on this line (correct/wrong) should be indicated in the text box with ID 4.
8. System of equations

In the edit mode, the editor of the answer shows:

\[
\begin{align*}
4x^2 - 15 + y^2 &= 0 \\
2xy &= 0
\end{align*}
\]

Variables (separated by commas): \(x, y\)

Answer model (tuple of numbers, like (0,0),(1,1)):

\((0, 4), (1, -4), (2, 0), (-2, 0)\)
9. Small formula (equation) answer box with pop-up

For a Small formula answer box and a Small equation answer box, the answer box can be set as pop-up. Settings:

This is what a student will see:

By clicking on \[\text{[button]}\], a pop-up appears that can be used to make stepwise the calculations.

The last answer automatically appears in the answer box.
10. Options for answers

For each answer box, the different settings to check the answer are possible. When checking students' answers, the selected options are considered.

a. Equivalent
The option Equivalent is selected by default. If this is the only selected option, every equivalent answer will be marked as correct final answer (the green tick mark appears).

b. Answer needed
The option ‘Answer needed’ only appears in the answer model for equations and is selected by default. However, tasks can be designed in which the final answer is an equation rather than a solution to an equation. This can for example happen in modeling assignments. In such cases, the option ‘Answer needed’ should be deselected.

c. Exact
With the option ‘Exact’ the designer can indicate that the solution should be written in the same form as the answer model. For solving equations, the option ‘Answer needed’ should also be selected.

Some trivial variations are allowed: if for example the answer model states $x + 3$, then $3 + x$ will also be marked correct. Is the student’s answer equivalent but not exactly the same, the orange tick mark will appear, together with the following feedback:

\[
x^2 = 121
\]
\[
x = \sqrt{121} \quad \text{or} \quad x = -\sqrt{121}
\]

Within the option ‘exact’ the designer can also allow more than one form to be marked correct. The alternative forms are separated by :: (two colons). Example:

\[
x = 3 \text{ or } x = 1 \frac{1}{2} :: 1.25
\]

For this equation, besides $x = 3$, both $x = 1 \frac{1}{2}$ and $x = 1.25$ will be accepted as final solution, whereas for example $x = \frac{5}{4}$ will not.

d. Form
By selecting the option Form, a formula editor appears in which a specific ‘form’ can be set, which a correct solution should have.

Example 1
If you want the final answer to be a fraction, the following will be inserted in the form-editor: $\frac{Q}{Q}$.

In this expression, $Q$ represents an arbitrary expression. The $Q$ in the numerator does not have to be the same expression as the $Q$ in the denominator.
The option ‘Answer needed’ actually is a special case of this option ‘Form’, namely the form $x=Q$ in which $Q$ is an arbitrary expression.

Example 2
Another task type is a task in which the equation for a line has to be found, in the form $ax + by = c$. The answer model would be: $y = 2x - 3$, and as correct form the following will be given: $2x - y = 3$.

This construction may seem devious. Wouldn’t it be easier to give in $2x - y = 3$ directly as the answer model? However, the answer model should always be in the form ‘variable = …’, as this allows for substitution and checking equivalency of expressions.

In the example above, equivalent expressions will not be recognized:
If the second answer should also be marked correct, it should be added to the form-box in the answer model:

\[ 2x - y = 3 \quad \therefore -2x + y = -3 \]

**e. Estimations**

In some tasks, an estimation of the correct answer is enough. This can be indicated in the answer model, using ±. For example, if the student’s answer should be between 60 and 70, the answer model can look like this:

**Answer model:**

\[ 65 \pm 5 \]
11. Substitutions in the answer model

The button \( \text{substitutions} \) in the answer model should not be confused with the substitution option for students when solving equations.

Here it concerns the possibility to perform substitutions behind the scenes:

Consider for example the following answer model and corresponding task:

We have assigned a value to the variables \( a \) and \( c \). This enables students to use these variables in their steps towards the final answer, instead of the values. In many solution strategies, such values are only substituted later in the process (the elaboration given above is common). Using this substitution construction, the intermediate steps can be checked.
This substitution option also offers the possibility to solve systems of equations.

\[
\begin{align*}
6x + 2y &= 56 \\
5x + 2y &= 48
\end{align*}
\]

In this example there are two answer boxes, but this is not necessary. In the answer model, \(x=8\) is given as the final answer. Moreover, \(y=4\) is given as a substitution. The other way around would yield a similar result.

Another notable aspect of this example is the absence of the arrow between lines.

This can be set by deselecting ‘Arrow’ in the answer box editor: 

When solving systems of equations, next equations may not follow directly from previous ones. It is more about combining different identities and equations in a smart way.
12. Test values

The DME checks for equivalence using a set of random test values from the so called test value interval, which is set on \([0; 5]\) by default. Usually this works fine, however for some specific tasks other test values are necessary. An example is the following task:

\[
\text{Simplify } \sqrt{x^2}. 
\]

The solution to this task should be \(|x|\), but if the DME only checks for positive values, the answer \(x\) will also be marked as equivalent. Therefore, the test value interval should be adjusted such that also negative values are checked. To do so, right click on ‘Equivalent’ in the answer box editor.

The following pop up appears:

Next fill in a new test value interval, for example \([-10; 10]\).

Note: the absolute value should be typed using the button \(|\]| or using F10, but not with the vertical bar | on the keyboard.