

## The use of mobile Internet devices in the formation of ICT component of bachelors in electromechanics competency in modeling of technical objects

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**Abstract.** Computer simulation of technical objects and processes is one of the components of the system of professional training of a modern electromechanics engineer. It has been established that despite the fact that mobile Internet devices (MID) are actively used by electrical engineers, the methods of using them in the process of bachelor in electromechanics training is considered only in some domestic scientific studies. The article highlights the components of the methods of using MID in the formation of the ICT component of the competence of the bachelor in electromechanics in modeling of technical objects, providing for students to acquire basic knowledge in the field of Computer Science and modern ICT and skills to use programming systems, math packages, subroutine libraries, and the like. For processing tabular data, it is proposed to use various freely distributed tools that do not significantly differ in functionality, such as Google Sheets, Microsoft Excel, for processing text data – QuickEdit Text Editor, Google Docs, Microsoft Word. For 3D-modeling and viewing the design and technological documentation, the proposed comprehensive use of Autodesk tools in the training process.

**Keywords:** Mobile Internet Devices, ICT Competencies, Electromechanics, Bachelors in Electromechanics.

## 1 Introduction

In previous papers we are discussed:

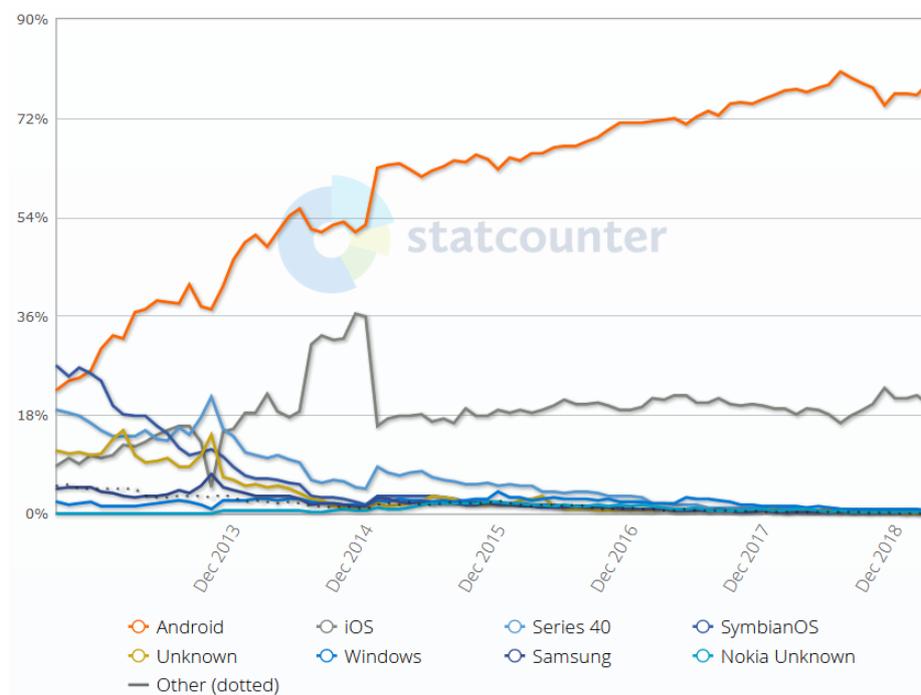
- the essence [11], content [17] and structure [16] of the competence of the bachelor in electromechanics in the design of technical objects as the system's property of the person formed in the process of learning, which contains the following components: cognitive-content (epistemological) – knowledge; operational-technological (praxeological) – skills, experience; value-motivational (axiological) – motivation, value relation; social-behavioral – sociability, ability to adapt, ability to integrate;
- on the basis of certain directions of professional training modernization of bachelor in electromechanics [12] a system of competences of a bachelor in electromechanics in modeling of technical objects was developed, which includes three groups of competences: general science (in information and communication technologies, in applied mathematics, in fundamental sciences), general professional and special professional;
- it is shown that the leading tools of forming the competence of the bachelor in electromechanics in the simulation of technical objects are MID – multimedia mobile devices that provide wireless access to information and communication Internet services for the collection, systematization, storage, processing, transmission, submission of all possible messages and data [14];
- the model of the use of MID in the formation of the competence of the bachelor in electromechanics in the modeling of technical objects [15] is developed. The implementation of this model in the study of bachelor in electromechanics of technical objects modeling is an appropriate method of use, the components of which are:
  - a. the method of using MID in the formation of the general scientific component of the competence of the bachelor in electromechanics in the modeling of technical objects;
  - b. the method of using MID in the formation of the general-professional component of the competence of the bachelor in electromechanics in the modeling of technical objects;
  - c. the method of using MID in the formation of a specialized and professional component of the competence of the bachelor in electromechanics in the modeling of technical objects.

## 2 The purpose and objectives of the study

The need to implement the developed model of the use of MID and defined the *purpose of the article* – to develop a methods of using MID in the formation of ICT component of bachelor in electromechanics competency in modeling of technical objects. To achieve this goal, the following *task* must be solved: to identify the leading mobile software tools for ICT competency development and illustrate their use in the disciplines “Computing and programming” and “Engineering and computer graphics”.

### 3 Results of the research

Smartphones are one of the most common among high-end Internet devices. According to the [9], at the beginning of 2018 in Ukraine mobile operating systems for Internet devices occupied the following parts of the market: Android 76.76%, iOS 18.78%, all others (SymbianOS, Windows, etc.) – 4.62%. Since November 2012, the part of SymbianOS and Android has equaled, and for now the part of Android in the domestic mobile operating systems market is steadily increasing, reaching 76.15% in February 2019 (Fig. 1). A similar analysis across different regions of the world shows a similar tendency, which gives an opportunity without loss of universality to illustrate the provisions of the developed methodology using the software tools running the Android operating system.



**Fig. 1.** Distribution of operating systems of MID in Ukraine (2009-2019) (according to [10])

The formation of such component of the competence of the bachelor in electromechanics in the modeling of technical objects, as competence in ICT, provides for the acquisition of basic knowledge in the field of computer science and modern information technologies by students; skills of using software and skills in computer networks, data transfer systems, ability to create databases and use Internet resources; the ability to use programming systems, mathematical packages, subroutine libraries, etc.

To process the table data in the course “Computing and programming” you can use a variety of freely distributed tools that have insignificantly different functionality. So, in content module 2 “Computing in Spreadsheet Environment”, Google Sheets [8] provide an opportunity:

- create new spreadsheets or edit existing files;
- share spreadsheets and collaborate in the same spreadsheet at the same time;
- work anywhere, anytime – even offline;
- add and respond to comments;
- format cells, enter or sort data, view charts, insert formulas, use find/replace and more;
- everything is saved automatically as user type;
- get insights, insert charts instantly and quickly, and apply formatting in one tap – with Explore;
- open, edit and save Excel and Calc spreadsheets [7].

The last actions are more natural to do with the help of the spreadsheet Microsoft Excel, whose mobile version is not inferior to desktops for functionality. Microsoft Excel contains a large number of templates that allow you to create spreadsheets quickly. The feature of the version of Microsoft Excel for MID with touch control is the ability to complete drawings, add handwritten notes and mathematical formulas using the tools tab “Drawing” (Fig. 2). As with Google Sheets, Microsoft Excel provides file sharing for viewing, editing, and commenting.

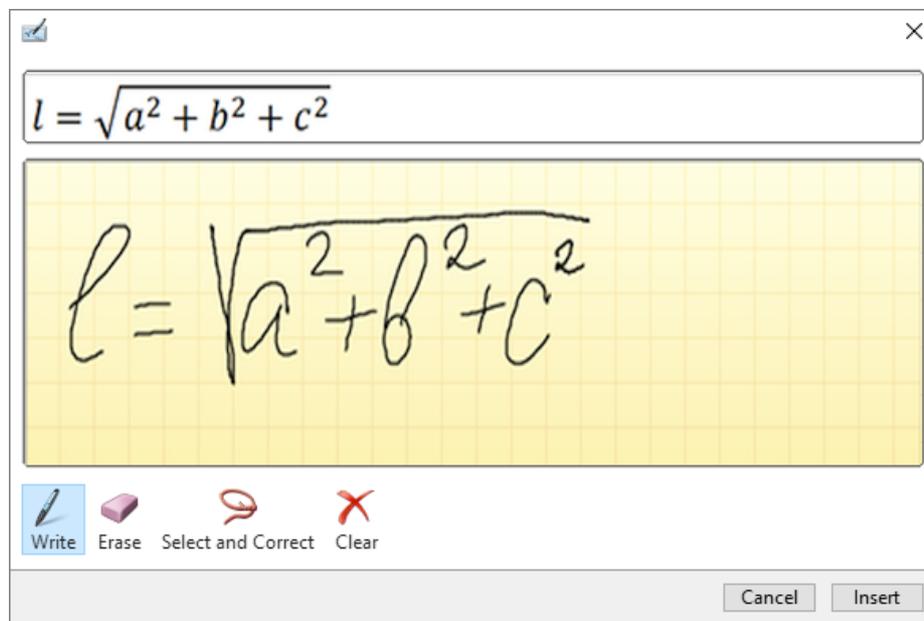


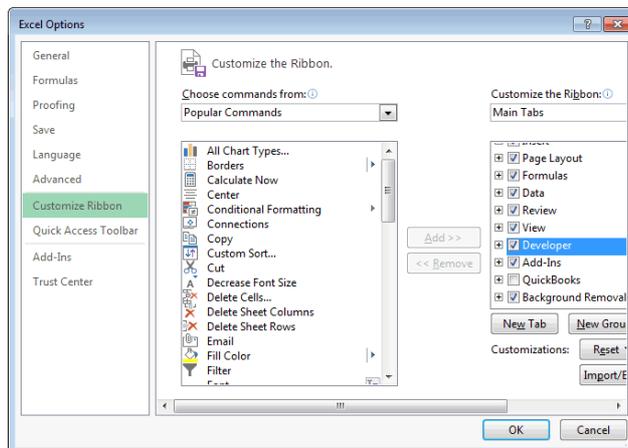
Fig. 2. Insert a handwritten formula in Microsoft Word 2016

Despite the fact that Microsoft Excel is a commercial product, for the most common MID with a screen size of 10.1 inches or less, Microsoft's license agreement provides the creation of a free account, the use of which enables the creation and editing of documents on devices. In addition, in studying content module 3 "Macros. Computing Automation" Microsoft Excel is a more convenient tool than Google Sheets. In particular, laboratory work 5 "Construction of macros" involves performing approximation of functions, construction of the trend line and statistical processing of experimental data.

You can start to perform laboratory work on any MID, for example, a tablet PC running with Android or Windows 10 – the version of Microsoft Excel, which is part of the Office 365 package, is freely available for educational institutions, and works with the same functionality under the managing of both mobile operating systems.

To start working with Visual Basic for Application in Microsoft Excel, you must initialize the spreadsheet by giving students access to the development tools (Fig. 3).

The next step is to create a workbook in Microsoft Excel. The new default book contains three worksheets. We will add two more to them, giving them the name: «Data», «X», «~X», «(~X)X», «(~X)Y», «SLAE». The choice of names is justified by the model used to approximate the results of the experiment using the least squares method.



**Fig. 3.** Configure the Developer pane in Microsoft Excel

In the first two columns of the "Data" sheet we will place experimental data – a column of independent variables  $x_{\text{exp}}$  and a column of dependent variables  $y_{\text{exp}}$ : A1 is  $x_{\text{exp}}$ , B1 is  $y_{\text{exp}}$ , A2:A12 are 11 values of  $x_{\text{exp}}$ , B2:B12 are corresponding 11 values of  $y_{\text{exp}}$ .

11 is not a fixed value – the number of points is set in the corresponding cell of the sheet «Data»: E1 is Number of points, F1 is an integer that determines the number of experimental data.

As an approximation model, we use the polynomial approximation:

$$y_{\text{calc}} = a_0 + a_1x_{\text{exp}} + a_2x_{\text{exp}}^2 + a_3x_{\text{exp}}^3 + a_4x_{\text{exp}}^4 + a_5x_{\text{exp}}^5 + a_6x_{\text{exp}}^6 + \dots + a_{10}x_{\text{exp}}^{10}$$

10 is the maximum degree of polynomial – to select a smaller one, we set it in the corresponding cell of the sheet “Data”: E2 is Polynomial order, F2 is an integer from 1 to 10, which is a polynomial order, E3 is Coefficients.

According to the chosen model, the order of the polynomial should not be equal or less than the number of points of experimental data – in the first case, instead of approximation, we get interpolation, and the second model just will not work. The designation of the coefficients ( $a_0, a_1, \dots, a_{10}$ ) will be placed in the range of E4:E14.

The calculated value of the polynomial will be placed in the cells of column C: C1 is  $y_{\text{calc}}$ , C2 is  $=\$F\$4+\$F\$5*A2+\$F\$6*(A2^2)+\$F\$7*(A2^3)+\$F\$8*(A2^4)+\$F\$9*(A2^5)+\$F\$10*(A2^6)+\$F\$11*(A2^7)+\$F\$12*(A2^8)+\$F\$13*(A2^9)+\$F\$14*(A2^10)$ . The cell C2 is copied to the following cells (C3, etc.) as many times as there will be experimental points (more precisely, one time less).

To determine the deviation of the experimental data of  $y_{\text{exp}}$  from the approximated  $y_{\text{calc}}$  we use the square of their difference: D1 is  $(y_{\text{calc}} - y_{\text{exp}})^2$ , D2 is  $=(C2-B2)^2$ . The cell D2 is copied to the following cells (D3, etc.) as many times as it was done in the previous case.

This initial completion of the output data and computational formulas is completed. The next step is to implement the least-squares method using Visual Basic for Application. The call to the corresponding program will be realized by the event “change of values on the worksheet” (Worksheet\_Change). Considering that the user can change the output data faster than the calculation is performed, it is necessary to secure from the new call of the computing subroutine until the completion of the current calculations. To do this, we create the corresponding variable:

```
Public recursion As Byte
```

Worksheet\_Change is a subroutine called when changing values on a worksheet:

```
Private Sub Worksheet_Change(ByVal Target As Excel.Range)
    If recursion = 0 Then
        recursion = 1
        Call createx
        Call transpx
        Call xtmulx
        Call xtmuly
        Call solve
        recursion = 0
    End If
End Sub
```

Sequential calls to all other procedures are performed with Worksheet\_Change only if its non-recursive non-execution is performed. Each procedure places data on its own worksheet in order for the user to verify the correctness of the implemented algorithm.

In the first step of the algorithm from the column with the experimental data  $x_{\text{exp}}$  creates a matrix  $\mathbf{X}$ , the number of rows of which is equal to the number of points of experimental data, and the number of columns is the order of the polynomial + 1. In the

first column of the matrix **X** the data of the  $x_{\text{exp}}$ , column, raised to the chosen order in the polynomial, in the second – the same data, elevated to the chosen order of the polynomial – 1, in the third – the same data, elevated to the chosen order polynomial – 2, etc. For the correct execution of these actions, the last column of the matrix **X** will contain the data of  $x_{\text{exp}}$ , elevated to zero degree, that is, 1:

```
Private Sub createx()
    n = Range("Data!$f$1").Value
    p = Range("Data!$f$2").Value
    For i = 1 To n
        For j = p To 0 Step -1
            Worksheets("X").Cells(i, p - j + 1).Value =
                (Worksheets("Data").Cells(1 + i, 1).Value) ^ j
        Next j
    Next i
End Sub
```

The second step of the algorithm involves the transposition of matrix **X**. Despite the fact that Microsoft Excel provides the built-in transposition function, the corresponding subroutine illustrates copying data from the worksheet «X» to the sheet «~X»:

```
Private Sub transpx()
    n = Range("Data!$f$1").Value
    p = Range("Data!$f$2").Value
    For i = 1 To n
        For j = 1 To p + 1
            Worksheets("~X").Cells(j, i) = Worksheets("X").Cells(i, j)
        Next j
    Next i
End Sub
```

The third step of the algorithm involves the construction of the main matrix of the system of normal equations, which is created by multiplying the transposed matrix from the sheet «~X» into the output matrix **X**. Analysis of the code of the subroutine gives an opportunity to conclude that the multiplication procedure of the matrices can be expressed through a series of scalar products of the vector lines on the vector column:

```
Private Sub xtmulx()
    n = Range("Data!$f$1").Value
    p = Range("Data!$f$2").Value
    For k = 1 To p + 1
        For j = 1 To p + 1
            s = 0
            For i = 1 To n
                s = s + Worksheets("~X").Cells(k, i).Value
                    * Worksheets("X").Cells(i, j).Value
            Next i
        Next j
    Next k
End Sub
```

```

    Worksheets("~X").Cells(k, j).Value = s
  Next j
Next k
End Sub

```

The fourth step of the algorithm is necessary to determine the right-hand side of the system of normal equations – the column of free members, which is formed by multiplying the transposed matrix  $\mathbf{X}$ , located on the sheet «~X», on the matrix-column  $\mathbf{Y}$ , formed from the column  $y_{\text{exp}}$ :

```

Private Sub xtmuly()
  n = Range("Data!$f$1").Value
  p = Range("Data!$f$2").Value
  For k = 1 To p + 1
    s = 0
    For i = 1 To n
      s = s + Worksheets("~X").Cells(k, i).Value
        * Worksheets("Data").Cells(1 + i, 2).Value
    Next i
    Worksheets("~X").Cells(k, 1).Value = s
  Next k
End Sub

```

The last step of the algorithm is to solve the formed normal system of linear algebraic equations with the left part, located on the sheet «(~X)X», and the right side of the sheet «(~X)Y». The results of the solution of the system and unknown coefficients of the polynomial:

```

Private Sub solve()
  srow = Range("Data!$f$2").Value + 1
  scol = srow + 1
  For i = 1 To srow
    For j = 1 To srow
      Worksheets("SLAE").Cells(i, j) =
        Worksheets("~X").Cells(i, j)
    Next j
    Worksheets("SLAE").Cells(i, j) =
      Worksheets("~X").Cells(i, 1)
  Next i
  Rem selection of the main element
  For i = 1 To srow
    emax = Worksheets("SLAE").Cells(1, i).Value
    num = i
    For j = i To srow
      If Abs(Worksheets("SLAE").Cells(j, i).Value) > Abs(emax) Then
        emax = Abs(Worksheets("SLAE").Cells(j, i).Value)
      End If
    Next j
  Next i

```

```

    num = j
  End If
Next j
If num <> i Then
  For k = 1 To scol
    temp = Worksheets("SLAE").Cells(num, k)
    Worksheets("SLAE").Cells(num, k) =
      Worksheets("SLAE").Cells(i, k)
    Worksheets("SLAE").Cells(i, k) = temp
  Next k
End If
Next i
For i = 1 To srow
  If Worksheets("SLAE").Cells(i, i).Value = 0 Then
    MsgBox ("Perhaps the matrix is degenerate")
  End If
Next i
Rem Gauss's row echelon form
For i = 1 To srow
  sw = Worksheets("SLAE").Cells(i, i).Value
  For j = 1 To scol
    Worksheets("SLAE").Cells(i, j).Value =
      Worksheets("SLAE").Cells(i, j).Value / sw
  Next j
  For k = i + 1 To srow
    c = Worksheets("SLAE").Cells(k, i).Value
    For j = 1 To scol
      Worksheets("SLAE").Cells(k, j).Value =
        Worksheets("SLAE").Cells(k, j).Value -
        Worksheets("SLAE").Cells(i, j).Value * c
    Next j
  Next k
Next i
Rem Gauss's reduced row echelon form
For i = srow - 1 To 1 Step -1
  s = 0
  For j = i + 1 To srow
    s = s + Worksheets("SLAE").Cells(i, j).Value
      * Worksheets("SLAE").Cells(j, scol).Value
  Next j
  Worksheets("SLAE").Cells(i, scol).Value =
    Worksheets("SLAE").Cells(i, scol).Value - s
Next i
Rem rewrite the results on the first sheet
For i = 4 To 14

```

```

Worksheets("Data").Cells(i, 6) = ""
Next i
For i = srow To 1 Step -1
    Worksheets("Data").Cells(srow - i + 4, 6) =
        Worksheets("SLAE").Cells(i, scol)
Next i
End Sub

```

The last procedure implements the Gauss method for solving systems of linear algebraic equations, the theoretical basis of which at the time of laboratory work (Fig. 4) students have already mastered in the course of higher mathematics.

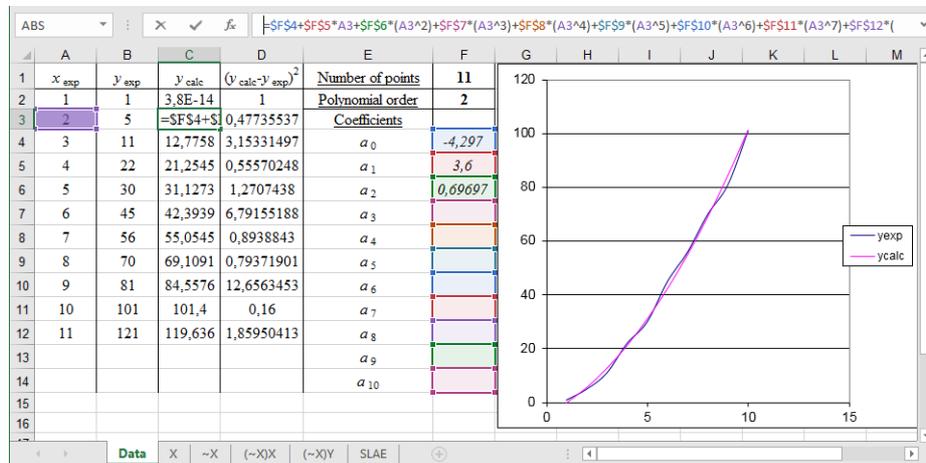


Fig. 4. The result of the laboratory work "Construction of macros"

Note that both spreadsheets provide the ability to perform actions on both stationary and mobile Internet devices, which creates conditions for their use in different forms of organization of the educational process. So, in a lecture on "Computer Science and Programming", the teacher can demonstrate work in the spreadsheet, giving students the opportunity to share the edited document. Under this approach, the role of the latter changes from the passive observer to the active participant (Fig. 5).

For the processing of text data in the course "Computer Science and Programming" you can use a variety of freely distributed tools that are significantly different in functionality – from the simplest text editors to advanced word processors.

The first category includes the QuickEdit Text Editor, which provides the ability to highlight syntax elements in more than 50 programming languages, Byte Mobile's Text Editor for editing HTML files, and more.

The second category includes word processors, among which you can distinguish Google Docs [6] that provide text documents with features equivalent to those provided by Google Sheets, and, in addition, the ability to open, edit and save Microsoft Word documents (Fig. 6).

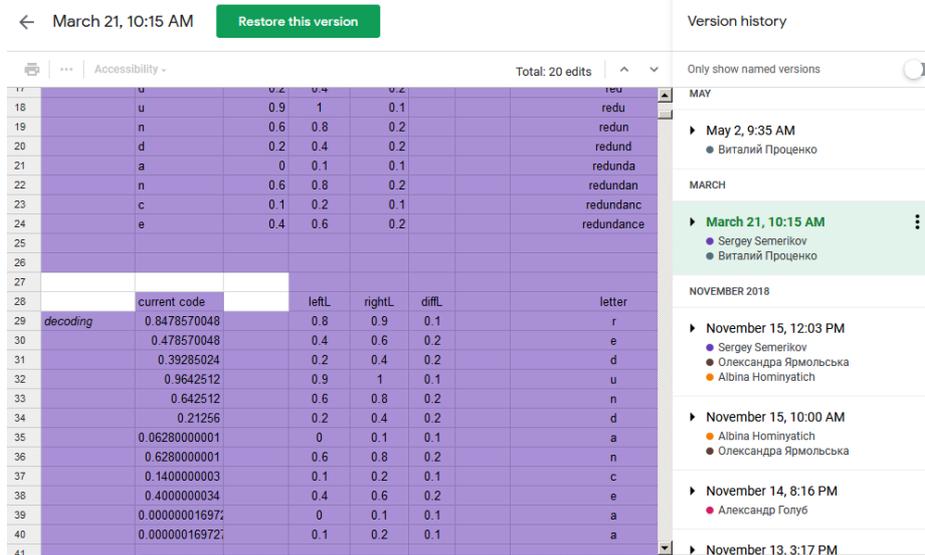


Fig. 5. Tracking student engagement in collaborative work in Google Sheets

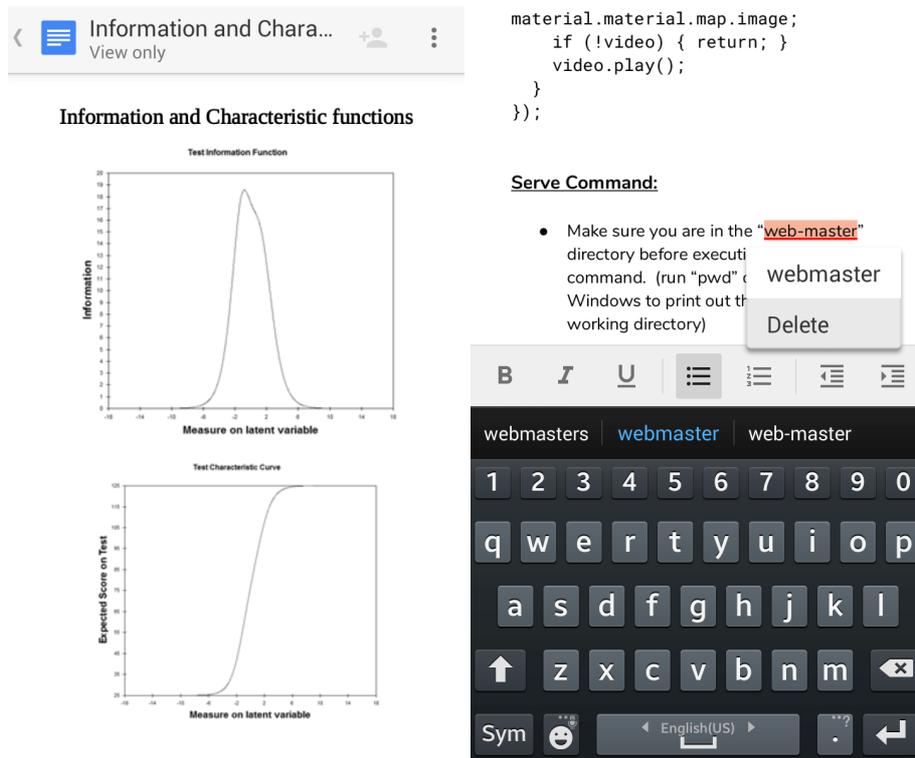
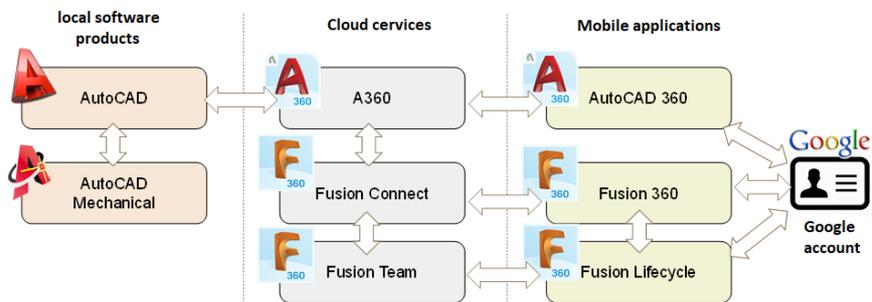


Fig. 6. View and edit Microsoft Word documents in Google Docs

The second academic discipline, in the learning of which is the formation of such an ICT component of the competence of the bachelor in electromechanics in the modeling of technical objects, is “Engineering and Computer Graphics”. In this discipline, bachelors in electromechanics learn to express technical ideas with the help of drawing. So, as a result of studying the discipline, the student must know the rules of execution and reading of design and technological documentation, be able to perform and read the drawings of technical objects, to prepare technological and design documentation in accordance with the standards.

Maryna V. Rassovytska and Andrii M. Striuk, based on the results of the study more than 30 mobile software tools for training engineering and computer graphics [18] have proposed a model for the integrated use of Autodesk tools in the process of training in engineering (Fig. 7).



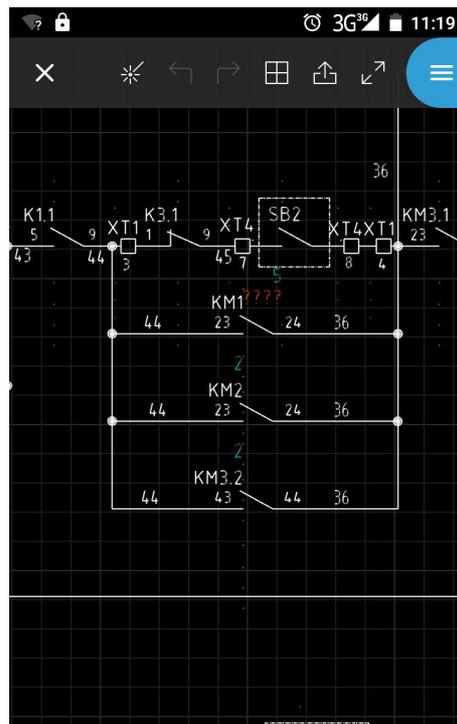
**Fig. 7.** Comprehensive use of Autodesk products in the training of future mechanics (by [18, p. 358])

For bachelors in electromechanics, the proposed model can be modified: instead of AutoCAD Mechanical we propose the use of Electrical (formerly – AutoCAD Electrical) [4], the method of which for the design of electric circuits is described in [3]. The use of Electrical in the teaching of engineering and computer graphics of bachelors in electromechanics provides the ability to form the skills of circuit design, the creation of qualitative documentation for electrical circuits, collaborative work with potential customers and suppliers, management of electromechanical projects, etc. The Electrical component includes graphic image libraries for electrical circuits and error checking tools that enable detection of problems before the start of the design phase of a technical system. Developers of Electrical indicate that it supports integration with Autodesk Inventor, and both of them together form an integrated solution for the design of mechatronic systems.

Autodesk provides Autodesk Inventor with a special free education license (free education license) intended solely for use by students and teachers for educational purposes. Functionally, this version of Autodesk Inventor does not differ from the full, with one exception: all files created or edited in it have a special flag (so-called educational flag) that will be placed in all views.

For MID running Android in 2019, a number of Autodesk tools are available.

AutoCAD - DWG Viewer & Editor [2] is a mobile version of the Autodesk main product – AutoCAD: a DWG file viewer with easy-to-use drawing and editing tools that enables you to view, create, edit and publish AutoCAD schemas and drawings on MID. Mobile AutoCAD can work in conjunction with desktop versions, which enables you to work continuously in a specialized computer classroom, general purpose audience, at home and on the road (Fig. 8).



**Fig. 8.** Using the AutoCAD mobile version – DWG Viewer & Editor for viewing and editing electrical circuits

Compared to the desktop version, AutoCAD mobile provides an opportunity:

- view and edit DWG files from device storage, email, or external cloud storage like Google Drive, Dropbox and OneDrive;
- select, move, rotate, and scale objects. View coordinates and properties;
- work offline and sync your changes once back online;
- share your CAD designs in the field.

All new AutoCAD users automatically receive a free 7-day free trial and students can sign up for a premium plan free of charge.

A360 - View CAD files [1] is a specialized browser for various 2D and 3D models created in AutoCAD (DWG), DWF, Inventor (IPT, IAM, IDW), Revit (RVT),

SolidWorks (SLDPRT, SLDASM, ASM) Navisworks (NWD, NWC), CATIA (CATPART, CATPRODUCT), Fusion 360 (F3D) and others. You can store model files in the same Autodesk cloud – <https://a360.autodesk.com>. This provides additional opportunities for collaborative work on models.

Fusion 360 [5] is a collaboration tool that combines the capabilities of CAD systems, CAMs and engineering calculations (CAEs). Unlike previous features, Fusion 360 provides the ability to execute 3D-designing of free-form models. The features provided by this tool are significantly dependent on the resolution of the screen of a MID: the larger it is, the more Fusion 360 elements become available to the user – from layer-by-view on a high-speed Internet device to engineering calculations on a device with a screen of 10 inches.

## 4 Conclusions

Thus, in the process of forming the ICT component of the competence of the bachelors in electromechanics in the simulation of technical objects, it is expedient to use the following MID software:

- cloud-based spreadsheets as modeling tools and text editors for program description of models;
- mobile computer-aided design systems for creating and viewing physical properties of models of technical objects;
- mobile communication tools for organizing joint modeling activities.

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