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Personalized Approach for Mobile Learning of Engineering Graphics*

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This paper presents the development, implementation and evaluation of an online tool for personalized mobile learning of engineering graphics. The online tool is designed to support the widespread mobile operating systems, such as Android, iOS, Windows 10 Mobile, as well as to be interactive and to enable "learning by doing". The framework for the developed tool includes Dropbox, as the file storage application, and AutoCAD 360, as an interactive CAD application with various tools for drawing. The study was conducted on a sample of 30 undergraduate students. The students were divided into the experimental group, using the developed online tool for personalized mobile learning, and the control group, using traditional learning tools. A statistical analysis of both samples was carried out in order to study the effectiveness of this online tool in the learning process. The results of the final test showed that the students from the experimental group were more successful than the students from the control group. Therefore, the use of the developed online tool for personalized mobile learning of engineering graphics can be considered an improvement in the teaching of engineering graphics.

Keywords: mobile learning; personalized learning material; engineering graphics

1. Introduction

The issue of online technologies for engineering education has become an important research topic in recent years. The following paragraphs provide a literature review of some engineering education research work, carried out in the field of online technologies for learning engineering graphics.

The interactive and modular web-based learning system CADFLASH was developed by P. P. Cerra et al. [1, 2]. This application, with tools commonly used in any 2D engineering drawing system, can help students learn engineering drawing employing an automatic correction mechanism. When a student does an exercise, the application gives them a mark based on the similarity with the correct answer. If the mark obtained is higher than the cut-off mark, the exercise was done successfully, otherwise the student has to redo it.

The online engineering drawing system HappyCAD was developed, as an e-learning tool in engineering graphics course, by M. Tsui and R. T. Lai [3]. The system includes instructional management and engineering drawing modules. The engineering drawing module provides three-dimensional (3D) models and interactive 3D solids. Learners can interact with the system and use various tools for drawing. Students can also receive feedback from teachers and redesign their engineering drawings.

The LMS platform, based on the Moodle system, was developed by S. Bogacki and E. Terczynska [4], as the tool of checking the progress in learning the engineering graphics. Two types of questions on the fundamentals of technical drawing have been used, i.e. "match the answer" and "multiple choice", to evaluate the student learning outcomes. Upon giving the answers, they were given feedback information involving a graphic file with correct answers.

An online intelligent system for teaching Computer Aided Design module, focused on using the AutoCAD software, was developed by A. Oraifige et al. [5]. The system was designed to guide students according to their abilities, offering progression through an individual learning plan that contained various educational methods. Formative assessment includes multiple choice questions on using AutoCAD to evaluate the student learning outcomes. Upon having provided their answers, they were given a comprehensive feedback and guidance based on their performance, instantly updated within their individual learning plan.

The outcome of this literature review has shown that some of online tools for learning engineering graphics employ personalized learning through an individual learning plan [5], while the others do not reap the benefits of such an approach [1–4]. Some of these online tools require interaction and use of various tools for drawing to solve "practice by doing" exercises [1–3], while the others use multiple choice and/or match the answer questions [4, 5]. Some online tools with "practice by doing" exercises use these exercises for automated evaluation of the student learning outcomes [1, 2], while the others evaluate the student learning outcomes with the involvement of the teacher [3]. Online tools with multiple choice and/or match the answer questions use students answers to these questions to evaluate the student learning outcomes [4, 5] and to update

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the individual learning plan based on this evaluation [5].

Unlike the traditional "one size fits all" learning approach, the personalized learning approach enables the most suitable choice of learning content, methods and technologies to achieve better learning quality and efficiency. Personalization leads to training programmes, customised to individual learners, based on an analysis of the learners objectives, current status of knowledge, learning styles, as well as constant monitoring of progress [6]. Mobile technologies such as smartphones and tablets facilitate anytime/anywhere access to online learning material compiled to meet personal needs and enable students to use their time more efficiently.

In order to determine the perception of the mobile learning of engineering graphics a survey was conducted among the students of the Faculty of Mechanical Engineering of the University of Montenegro [7]. This study revealed that the students have got a positive perception of mobile learning considering it to be convenient both for communication with other students and for an access to the course content. The students also like to learn with mobile devices and consider the mobile learning to be useful for the course in engineering graphics. Such a positive perception towards the mobile learning might be based on the fact that all students use mobile devices on a daily basis. The results of this survey are in line with the findings of other researchers saying that the students using technology in everyday life also become willing to use technology in their education [8, 9].

According to the presented results of the conducted survey, the initial hypothesis about the mobile learning of engineering graphics was set. According to this hypothesis, the mobile learning of engineering graphics will lead to the improvement of students' success in examinations.

This paper presents development, implementation and evaluation of an online tool for personalized mobile learning of engineering graphics. The online tool was designed to support the widespread mobile operating systems, such as Android, iOS, Windows 10 Mobile, as well as to be interactive and to enable "learning by doing". The framework for the developed tool includes Dropbox, as the file storage application and AutoCAD 360, as an interactive CAD application with various tools for drawing. Both applications are available via free download from App Store (iOS), Google Play (Android) and Microsoft Store (Windows 10 Mobile). This online tool, developed like an e-book combining a reading material with "practice by doing" exercises, exploits the possibilities of Dropbox to share the learning material uploaded to the cloud and the possibilities of AutoCAD 360 to do the "practice by doing" exercises. This e-book also enables the comparing of student's solution of the "practice by doing" exercise with the correct solution that is also uploaded and accessible in the cloud. The basic limitation of this work is related to the limited AutoCAD 360 feature set which influences the level of complexity of "practice by doing" exercises. Anyway, AutoCAD 360 feature set is continually upgraded overcoming this limitation with every new release of this CAD application.

The current level of student's knowledge is used to personalize the content of e-book for each student. The analyzed engineering education research works used multiple choice and/or match the answer questions, and solutions to "practice by doing" exercises to evaluate the student learning outcomes. Multiple choice and/or match the answer questions provide unprepared students the opportunity to guess, and for the right guesses they get credits for things they do not know. On the other hand, a successful completion of "practice by doing" exercises is not a guarantee that the student will successfully complete the real-world engineering drawings, that are more complex than any of the "practice by doing" exercises. Therefore, the evaluation of the student outcomes based on the results of multiple choice and/or match the answer questions, and solutions of the "practice by doing" exercises can result in a wrong evaluation of a student's knowledge. Because of that, the presented approach relies on the Professor's evaluation of the students tests, completed during the course, to determine the level of each student's knowledge.

2. Development of personalized learning material for mobile learning of engineering graphics

Continuous learning, creative thinking and ability to solve problems have to be substantial learning outcomes in the engineering education. Accordingly, the methods of teaching and learning in the field of engineering are equally important as the carefully selected content of the fields knowledge itself [10].

The learning pyramid, shown in Fig. 1, points out the importance of a combination of different methods of knowledge presentation in order to achieve the learning outcomes. A good learning material related to the learning environment and compatible with the needs of students can attract students to use it. In order to develop such a learning material for mobile learning of engineering graphics the learning pyramid guidelines are used for its development.

The students of the Faculty of Mechanical Engineering are introduced to computer aided drafting throughout the course in engineering graphics. The

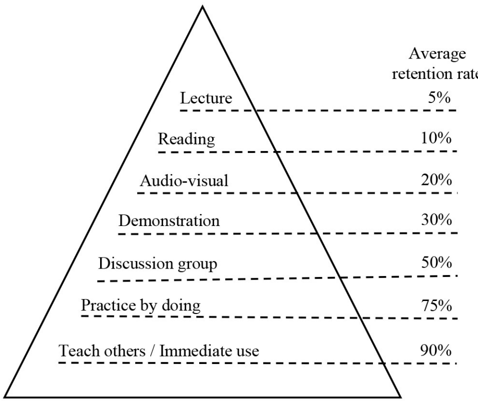


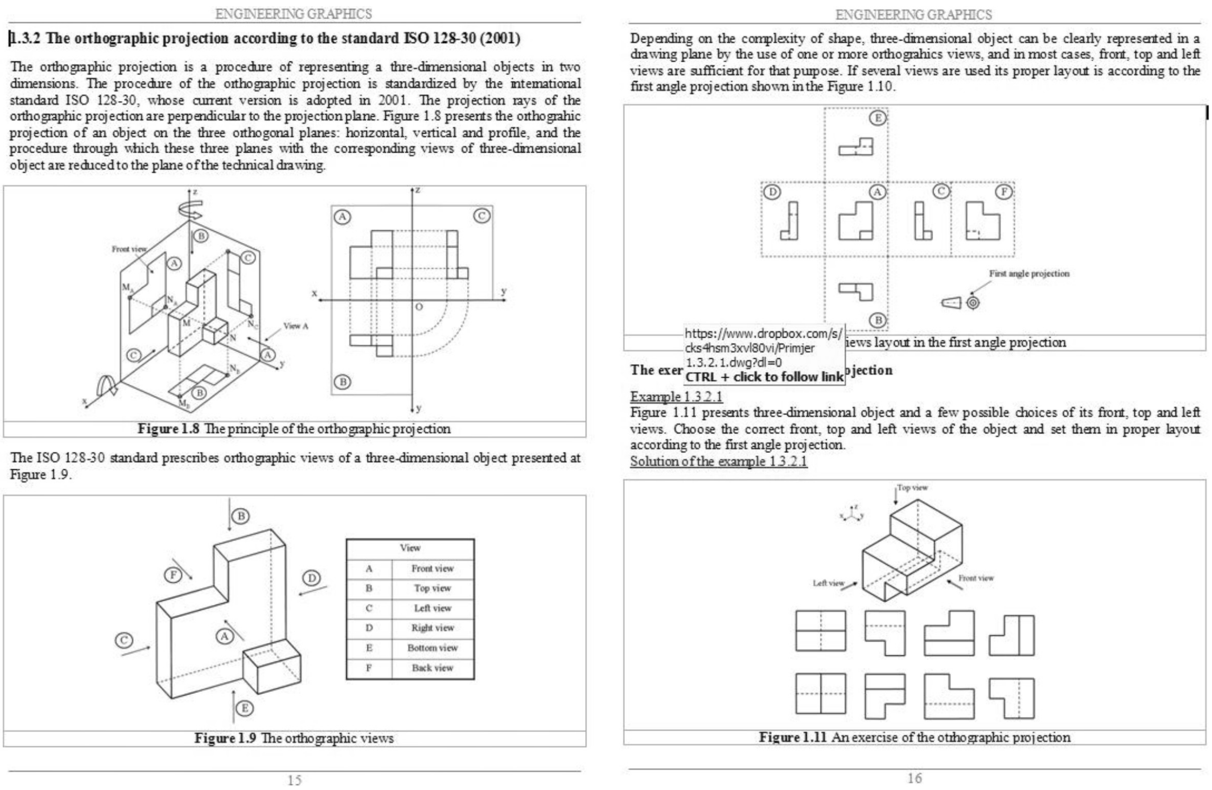
Fig. 1. The learning pyramid showing how much of material the learners retain [11].

released iOS version of AutoCAD 360 for the iPhone, iPod Touch and iPad, followed by the version for Android phones and tablets, enables the use of AutoCAD as a new drafting tool for the mobile learning. AutoCAD 360 is an account-based mobile and web application enabling the registered users to view, edit, and share AutoCAD files via mobile devices and web using a limited AutoCAD feature sets and cloud-stored drawing files [12]. It also allows the running of mobile apps on mobile devices, such as tablets, notebooks and smartphones. The major benefit of Autodesk 360 is that one can access it wherever there is a connection.

The course instructional material for presentation of the learning content is developed as an e-book combining a reading material with the "practice by doing" exercises and planned to be released as a Word document. Since the engineering students usually have good abilities to "learn by doing" [13], technologic advancement could be used as a catalyst of innovative methods in teaching and learning process. That is why a deeper learning and longer retention of what has been learnt is supported by the "practice by doing" exercises developed for AutoCAD 360 environment.

The "practice by doing" exercises from this e-book and their solutions are uploaded in AutoCAD format to the cloud. Each chapter of this e-book is followed by numerous "practice by doing" exercises and its hyperlink references to the URL for the "practice by doing" exercise and solutions as shown in Fig. 2. After reading some of the chapters, a student can use the hyperlink references to open the files with "practice by doing" exercises on his/her mobile device in order to practice the chapter content. After the completion of a "practice by doing" exercise using AutoCAD 360, a student can open a file with the exact solution of the exercise in order to compare it with their own solution.

The "practice by doing" exercises are developed to allow an AutoCAD 360 user to work comfortably despite the limited AutoCAD feature set, to be


ENGINEERING GRAPHICS

1.3.2 The orthographic projection according to the standard ISO 128-30 (2001)

The orthographic projection is a procedure of representing a thre-dimensional objects in two dimensions. The procedure of the orthographic projection is standardized by the international standard ISO 128-30, whose current version is adopted in 2001. The projection rays of the orthographic projection are perpendicular to the projection plane. Figure 1.8 presents the orthograhic projection of an object on the three orthogonal planes: horizontal, vertical and profile, and the procedure through which these three planes with the corresponding views of three-dimensional object are reduced to the plane of the technical drawing.

Figure 1.8 The principle of the orthographic projection

The ISO 128-30 standard prescribes orthographic views of a three-dimensional object presented at Figure 1.9.

View	
A	Front view
B	Top view
C	Left view
D	Right view
E	Bottom view
F	Back view

Figure 1.9 The orthographic views

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Depending on the complexity of shape, three-dimensional object can be clearly represented in a drawing plane by the use of one or more orthograhics views, and in most cases, front, top and left views are sufficient for that purpose. If several views are used its proper layout is according to the first angle projection shown in the Figure 1.10.

First angle projection

https://www.dropbox.com/s/cks4hsm3xvl80vi/Primjer 1.3.2.1.dwg?dl=0
CTRL + click to follow link

iews layout in the first angle projection

The exer ojection

Example 1.3.2.1
Figure 1.11 presents three-dimensional object and a few possible choices of its front, top and left views. Choose the correct front, top and left views of the object and set them in proper layout according to the first angle projection.
Solution of the example 1.3.2.1

Top view
Left view
Front view

Figure 1.11 An exercise of the othographic projection

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Fig. 2. Pages of e-book with reading material and "practice by doing" exercises.

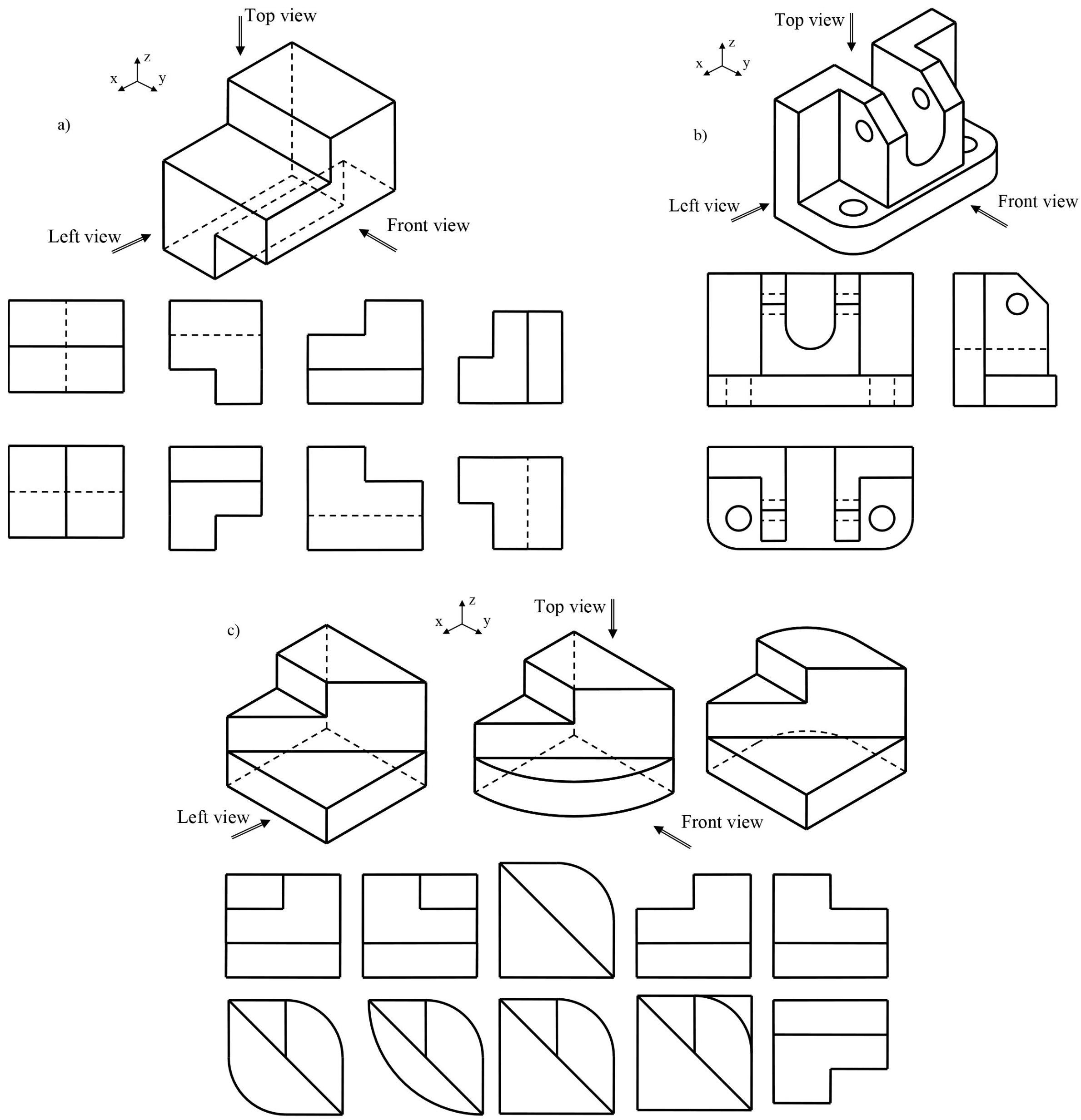

Fig. 3. 'Practice by doing' exercises of orthographic projection.

as simple as possible and to facilitate the achievement of the desired learning outcomes. Figs. 3, 4 and 5 present a few examples of the ''practice by doing'' exercises. Fig. 3 presents several examples of the exercises of an orthographic projection. In the exercise given in Fig. 3a, it is necessary to choose among the given drawings and select those representing front, top and left views of a 3D body from this figure and set them in proper layout according to the first angle projection. In the exercise given in the Fig. 3b, it is necessary to correct errors in the front, top and left views of 3D body from the same figure. In the exercise from Fig. 3c, it is necessary to choose among the given drawings and select those representing the front, top and left views of one of 3D bodies from the same figure and set them in the proper layout according to the first angle projection.

Figure 4 presents several examples of exercises in dimensioning of multiviews drawings. In the exercise given in Fig. 4a, it is necessary to correct the errors in the dimensioning of the multiviews drawing. The exercise given at Fig. 4b presents a correctly dimensioned multiviews drawing where it is necessary to correct errors in the position of the machining marks.

Figure 5 presents an example of exercises in dimensioning according to the machining operations applied to manufacture some machine part. In this exercise, it is necessary to correct the errors in the dimensioning of a machine part which is man-

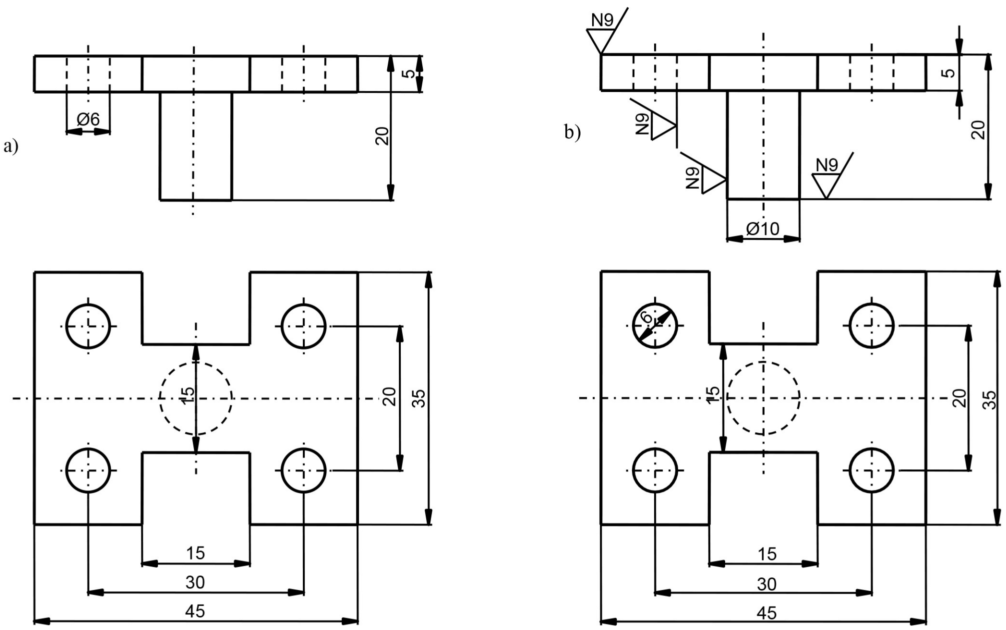

Fig. 4. "Practice by doing" exercises of dimensioning.

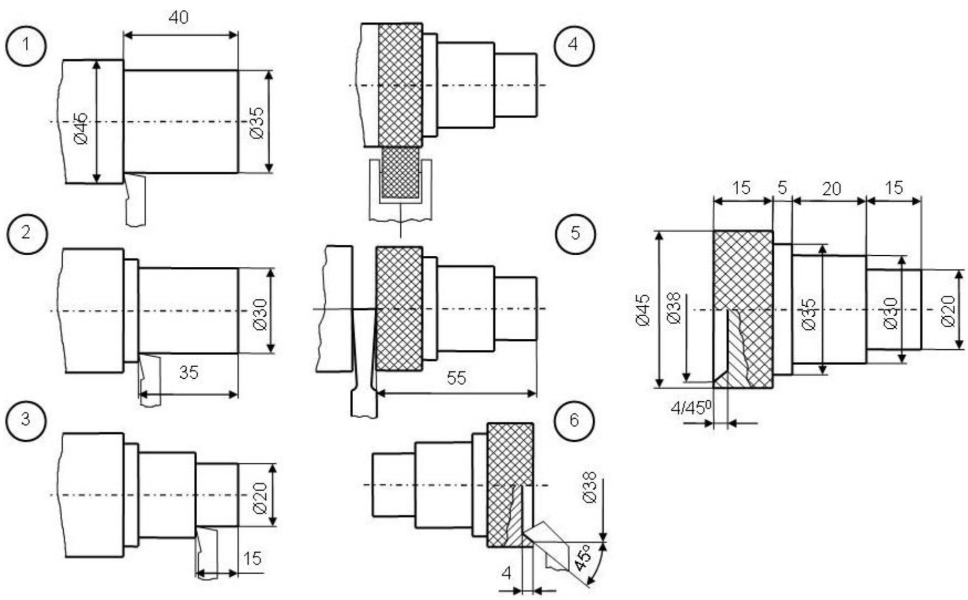

Fig. 5. "Practice by doing" exercise of dimensioning [14].

ufactured by six turning operations presented at the same figure.

This study aims to find out if the mobile learning can be effectively used to achieve better learning outcomes in the area of engineering graphics. The experiment was conducted on a sample of 30 undergraduate students. The students, who attended the engineering graphics course, were divided into an experimental and a control groups. Both groups were made of 15 randomly chosen students. The students from the experimental group had lectures presented in a traditional way supported by learning material for mobile learning as shown in Fig. 6, while the students from the control group had lectures presented only in the traditional way.

At the beginning of the course, each student from the experimental group got his/her own space in the cloud with the same set of uploaded "practice by doing" exercises and an identical e-book from engineering graphics. During the course, each student completes three tests. After each test, the complete analysis of tests of all students from the experimental group was carried out in order to identify the gaps in knowledge for each of the students and, on the basis thereof a personalized upgrading of e-books was carried out for each

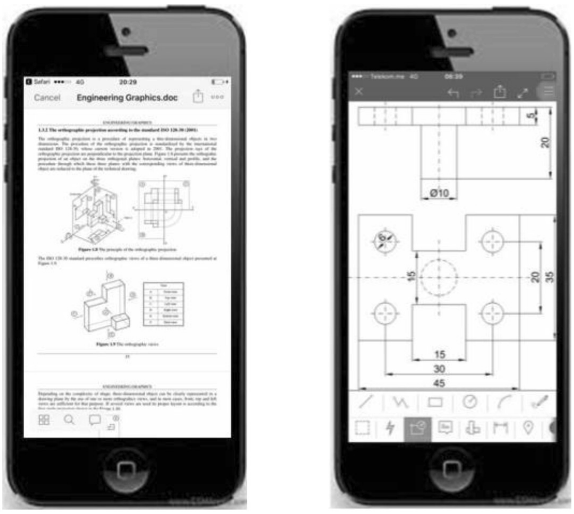

Fig. 6. Learning material on smartphone.

student by uploading of additional "practice by doing" exercises in the cloud that should enable each student to correct the identified gaps in their knowledge. Through such an approach, lasting to the end of the course in the engineering graphics, a personalized learning material was developed and was adjusted to the needs of each individual student from the experimental group. The students from the experimental group have used such a personalized e-books during the preparations for the final test in the engineering graphics.

3. Results and discussion

3.1 Evaluation of impact of personalized approach for mobile learning of engineering graphics on students' learning outcomes

With the aim of measuring the results, the final test that the students had taken at the end of semester was used. In the final test, the students were solving problems in technical drawing. A typical task in the test included the following requirements: (1) Drafting multiview drawing, involving some section view, based on the 3D model of a machine part; (2) Choosing the proper paper size, setting the proper scales for drawing and specific details; (3) Dimensioning multiview drawing. The test applied in the experiment was a standard test used for testing previous generations of students.

The distribution of grades in the experimental and the control groups is shown in Table 1. Grades range from E to A (equivalent to the grading scale 6 to 10).

A descriptive, comparative, statistics of results achieved in the final test is presented in Table 2.

The presented data obtained during the final examination in the engineering graphics were used

Table 1. Distribution of grades achieved on the final test

	A	B	C	D	E
1. Experimental group	9	4	1	1	0
2. Control group	4	5	3	2	1

Table 2. Descriptive comparative statistics of the results achieved in the final test

	Number of students—n	**Mean—$\bar{x}$**	**Standard deviation—s**
1. Experimental group	15	9.40	0.88
2. Control group	15	8.60	1.20

to test the initial hypothesis stating that the mobile learning of engineering graphics will lead to a greater success of the students in examinations. For that purpose a null hypothesis was defined, which claimed that the success of the students having lectures presented in the traditional ways supported by mobile learning materials and the success of the students having lectures presented only in the traditional ways, will be equal:

$$H_0 : \mu_1 = \mu_2 \tag{1}$$

μ_1 and μ_2 are mean grades of both groups of students. An alternative hypothesis was also defined and it stated that the success of the students having lectures presented in the traditional way supported by mobile learning materials will be better compared to the students having lectures presented only in the traditional ways:

$$H_1 : \mu_1 > \mu_2 \tag{2}$$

The hypothesis test by way of two small samples $n < 30$, experimental ($\bar{x}_1$,s_1) and control group ($\bar{x}_2$,s_2), is carried out by means of the variable representing the difference $\bar{x}_1 - \bar{x}_2$ [16]. The standard deviation of this variable can be determined through the expression:

$$s_{\bar{x}_1-\bar{x}_2} = \sqrt{\frac{(n_1 - 1) \cdot s_1^2 + (n_2 - 1) \cdot s_2^2}{n_1 + n_2 - 2}} \cdot \sqrt{\frac{1}{n_1} + \frac{1}{n_2}} = 0.384 \tag{3}$$

The variable obtained according to the expression:

$$t = \frac{\bar{x}_1 - \bar{x}_2 - (\mu_1 - \mu_1)}{s_{\bar{x}_1-\bar{x}_2}} \tag{4}$$

has Student's distribution with $k = n_1 + n_2 - 2 = 28$ degrees of freedom. If the null hypothesis is correct $H_0 : \mu_1 = \mu_2$ then expression (4) is simplified:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s_{\bar{x}_1 - \bar{x}_2}} = 2.083 \quad (5)$$

The test of null hypothesis accuracy will be carried out with the risk probability $p(|t| > t_p^k) = 0.05$ to which applies $t_{0.05}^{28} = 2.048$ [16]. Given that $|t| > t_{0.05}^{28}$ the null hypothesis H_0 is discarded as incorrect and with the risk probability of $p = 0.05$, it can be concluded that the difference between the mean values of the knowledge of the students from the experimental and the control groups $\bar{x}_1 - \bar{x}_2$ is meant to be significant and that the students from the experimental group are more successful at examinations than the students from the control group.

3.2 Survey of students' perception on learning materials for mobile learning of engineering graphics

The results of the presented quantitative analysis show that the personalized approach to mobile learning, beside the traditional ways of teaching of the engineering graphics, contributes the achieving of the students' better results in examinations. Such results are expected because many of the students entering university have grown up with mobile devices, use this technology in everyday life which also makes them willing to use mobile devices in their education.

Besides the quantitative analysis, a qualitative analysis of the personalized approach for mobile learning of the engineering graphics was also carried out. For this analysis, a survey questionnaire was developed for data collection in order to investigate the students' perception of the materials for the mobile learning of the engineering graphics. All students from the experimental group participated in the survey at the end of the course in the engineering graphics. The most important aims of the study were to find out if there was an orientation toward this concept, regarding its usefulness and simplicity, and to find out the students' opinion of the directions for the quality improvements of the material for mobile learning.

The questionnaire consisted of 10 positive and negative statements in order to prevent any response set. Several statements from other studies were used for this study to meet its aim [17]. A five-point Likert scale (1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree) was used to express students' perception on each statement [18]. Cronbach's Alpha Coefficient, used to test the internal consistency of the questionnaire, is mathematically defined as follows:

$$\alpha = \frac{k}{k-1} \cdot \left(1 - \frac{1}{s_T^2} \cdot \sum_{i=1}^{k} s_i^2\right) \quad (6)$$

k is a number of statements, s_i is a standard deviation of i-th statement and s_T is a standard deviation of the total of all k statements scores [19]. The major findings for the students' opinion measures, found in the questionnaire, are reported in Table 3.

A rule of thumb that has been recommended in the literature requires that Cronbach's alpha of an internally consistent questionnaire be equal to 0.70 or more [20]. In this study, Cronbach's alpha, calculated to be 0.84, showed a good internal consistency of the questionnaire.

The results of the study show that the highest means are for the statements 6 and 5 and the lowest means are for the statements 7, 8 and 3, measuring the students' perceptions of the mobile learning materials. This result reveals that the students have got positive perceptions of the learning materials. The students prefer "practice by doing" exercises to the reading materials and they found the number of the "practice by doing" exercises to be insufficient. The students also considered the learning materials easy to use.

The students were also asked to give their opinions about the possibility of the improvement of the learning material quality which resulted in a

Table 3. Results of survey on students' perceptions of mobile learning material

No.	Statement	Mean	St.Dev.
1.	The level of the content of text-based learning materials is appropriate	4.40	0.66
2.	Text-based learning materials are effective at enabling me to meet the specified learning objectives	4.10	0.94
3.	I like to use text-based learning materials	3.90	0.70
4.	The level of "practice by doing" exercises is appropriate	4.50	0.67
5.	"Practice by doing" exercises are effective at enabling me to meet the specified learning objectives	4.60	0.66
6.	I like to use "practice by doing" exercises	4.60	0.49
7.	Number of "practice by doing" exercises is sufficient	2.80	0.60
8.	It is difficult to use the learning materials	3.10	0.70
9.	I have understood the course content better after using the learning material	4.40	0.80
10.	The learning material has enhanced my interest in the area studied within the course	4.20	0.87
	The total of all 10 statements:	40.40	4.63
	Cronbach's alpha:	0.84	
	Number of students included in survey:	15	

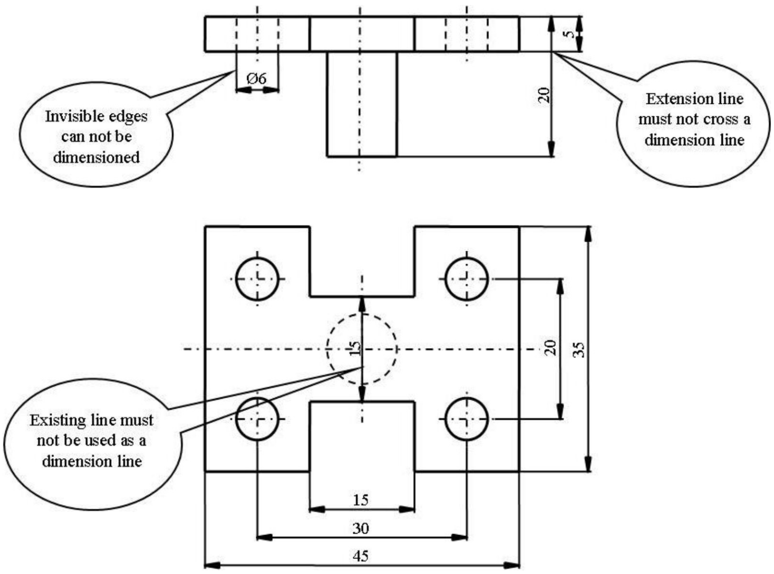

Fig. 7. "Practice by doing" exercise with additional notes.

significant number of suggestions, that will be used during the next reconstruction of the learning material in order to improve its quality. The following useful suggestions, obtained as a result of the students' survey, were put forward:

1. To increase the number and versatility of the "practice by doing" exercises;
2. To amend the solutions of the "practice by doing" exercises with the comments about the reasons for corrections that are necessary to be made as presented at Fig. 7;
3. For the "practice by doing" exercises, where it is necessary to select orthographic projections of a body and set them in the proper layout according to the first angle projection, the orthographic projections should be in the form of blocks so as to be more easilly selected and moved to the right position.

4. Conclusion

The main contribution of this paper is the introduction of a new personalized approach to the development of the teaching material for a mobile learning of the engineering graphics that is adjusted to the needs of each individual student. The course instructional material for the presentation of the learning content is developed as an e-book, combining the reading material with the "practice by doing" exercises planned to be released as a Word document. Besides the reading material, a large number of the "practice by doing" exercises were developed for AutoCAD 360, which is used as a new drafting tool for the mobile learning of the engineering graphics. The "practice by doing" exercises were developed to enable the AutoCAD 360 users to work comfortably despite the limited AutoCAD feature set. During their development, a particular attention was paid to making them as simple as possible enabling the students to master the rules of technical drawing.

The findings of this study contribute to a better understanding of the students' perceptions of the developed learning material. The results of this study revealed that the students positively accept the mobile learning and that they are willing to use it, especially the "practice by doing" exercises. These findings are consistent with the results of other researches, presented in the available literature about the topic. The students are also very willing to contribute to the improvement of the quality of the learning material for mobile learning that resulted in a huge number of useful suggestions. The results of this research have shown that the students using personalized learning material for mobile learning of the engineering graphics achieved better results in the final test. This study validated the usefulness of a new personalized approach for mobile learning of the engineering graphics.

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