

THE IMPACT OF DIGITAL LEARNING MATERIALS ON ENHANCING MATHEMATICAL KNOWLEDGE: THE COLLEGE STUDENT'S POINT OF VIEW

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Abstract: This paper explores the impact of digital learning materials on enhancing mathematical knowledge of the college students. The study explores opinions and insights gathered from students regarding the effectiveness of digital learning platforms such as Google Classroom, Google Drive, etc. Key areas of this paper focus on identifying the types of most beneficial digital materials and on the role of electronic materials in motivating students for learning, and the comparative efficacy of in-person versus online learning in mathematics education. Furthermore, the paper examines the potential benefits of incorporating innovative learning models, such as interactive quizzes, competitions, simulations, and educational apps, into the curriculum. The results provide valuable insights into student's preferences and the potential for digital tools to enhance mathematical learning outcomes. The findings suggest that while digital materials are generally well-received, the incorporation of interactive contents significantly enhances student engagement and learning efficiency.

Key words: Digital materials, Electronic learning, Mathematics, College education

1. INTRODUCTION

In the digital age we are living, education has undergone a significant transformation, with digital learning materials playing one of the central role in modern pedagogy. The integration of online platforms and electronic resources has revolutionized the way students engage with mathematical contents, providing new opportunities for interactive and personalized learning experiences. This paper aims to explore the impact of digital learning materials on enhancing mathematical knowledge from the student's point of view. The benefits of digital learning materials are well known and proven [1]. Despite advantages, there is still a need to understand how students perceive the effectiveness of digital learning materials. This paper seeks to fill this gap by discussing the results of a comprehensive survey conducted among students. The survey examines various aspects of digital learning, including the types of materials deemed most beneficial, the role of electronic resources in motivating students, and the comparative efficacy of in-person versus online learning in mathematics education.

By presenting the student's perspectives, this paper provides valuable insights into the potential of digital tools to enhance mathematical learning outcomes, at the college level. The findings suggest that while digital materials are generally well-received, the incorporation of interactive and engaging contents significantly enhance student's engagement and learning efficiency.

2. DIGITAL LEARNING MATERIALS IN MATHEMATICS EDUCATION

Recent research of digital learning materials emphasizes the positive impact on enhancing student's mathematical knowledge. There are many theories which support the benefits of integrating digital tools and materials into education, at all levels and in all fields.

The Constructivist learning theory claim that the interactive digital environments contribute to active engagement of students and enable them to explore and manipulate concepts for deeper understanding [2]. Cognitive Load Theory highlights the importance of designing content to manage cognitive demands and integrate multimedia [3], [4].

The Self-Determination theory implies that personalized digital experiences promoting autonomy and competence additionally boost the motivation [5]. Features like self-paced learning and immediate

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feedback enhance student's confidence and engagement. Similarly, the Technology Acceptance Model underscores that intuitive, useful digital tools increase learning outcomes, with students valuing the convenience and collaboration these platforms offer [6].

The Media Richness theory highlights the value of rich media, such as videos and simulations, in simplifying complex concepts and fostering deeper understanding [7]. Interactive simulations, for instance, make abstract ideas more accessible and engaging. Rich media can convey complex mathematical concepts more effectively than text alone, making it easier for students to grasp abstract ideas. Interactive simulations, for example, allow students to visualize and manipulate mathematical models, which can lead to a more profound and intuitive understanding of the subject matter.

Together, these theories provide a comprehensive understanding of how digital learning materials can significantly improve student outcomes in general, and especially in mathematics. The integration of digital tools in education can not only support active and engaging learning but also can address diverse learning needs and preferences. By leveraging the strengths of digital platforms, educators can create more effective and motivating learning environments that enhance student's mathematical knowledge and skills.

3. APPLICATION OF DIGITAL LEARNING MATERIALS IN COLLEGE MATHEMATICS EDUCATION

Most first-year undergraduate students in the Higher Education Technical School of Professional Studies in Novi Sad take a mathematics course. The mathematics course includes topics from algebra (Mathematical logic, complex numbers, matrices, determinants, systems of equations) and analysis (Real functions of real variables, limits, derivatives, applications of derivatives, analysis of functions and graph plotting, indefinite integrals, definite integrals and their applications). To help students master the material more easily, a large amount of digital teaching materials of various types have been created. The materials are published on a public Google Drive folder, Figure 1a). As one can see, the folder is organized in the manner that every topic has its subfolder. Each subfolder contains a file with the lecture and another file that contains a link to a video published on YouTube, containing solved examples from the topic, Figure 1b). Figure 1c) shows video materials with the explanation of steps for solving colloquium exercises.

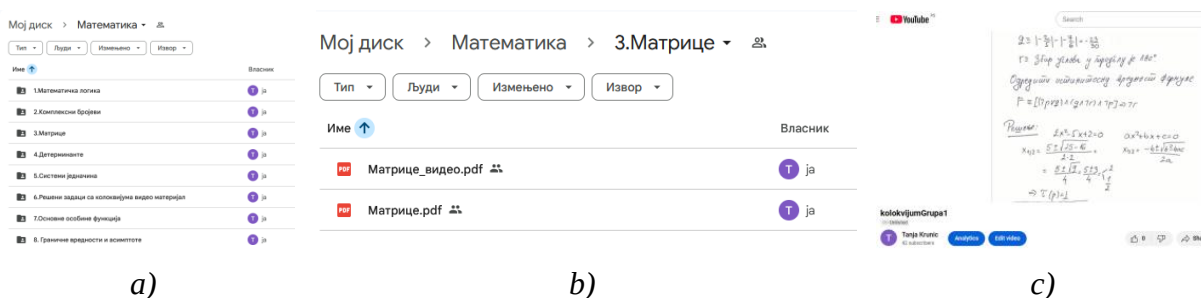


Figure 1 - Subject Google drive folder (a), topic subfolder content (b), video material (c)

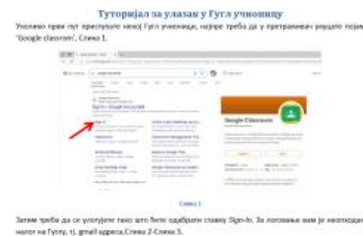
For the purpose of sharing digital materials for exercises, two Google Classrooms for two large groups of students are created. The subject's Google Drive contains a subfolder with a connection to the Google Classrooms. Namely, there are two files containing the appropriate passcodes to the classrooms, Figure 2a). To additionally support the students, there is also a tutorial for accessing the classrooms, Figure 2b).

Мој диск > Математика > Вежбе > 📄

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Име	Власник	Датум измене
ТUTORIJAL ZA UPAAK U GUGL UČIONIČU.pdf 📄	ja	4. 11. 2024. ja
Google učionica prof T. Sekuliћ.docx 📄	ja	28. 10. 2024. ja
Google učionica prof. C. Nikoliћ.docx 📄	ja	4. 11. 2024. ja

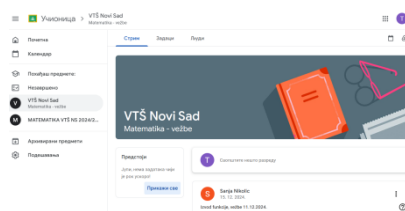
a)



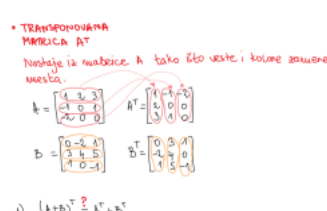
b)

Figure 2 – Files with Google classrom passcode (a) and Google Classroom tutorial (b)

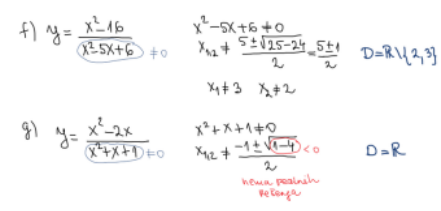
Each Google classroom (Figure 3a)) contains a series of documents with solved exercises on all topics of the subject. Figure 3b) shows solved problems in the field of matrices, whereas Figure 3c) shows steps for determining the domain of functions. As we can realize, important details are colored with different colors, so students can more easily identify and understand them.



a)



b)



c)

Figure 3 – Google classrom (a), Matrices (b), Domain of functions (c)

To increase students' interest, students are provided with two interactive tutorials created especially for this subject using the Wolfram Mathematica programming language [8] and posted on the Wolfram cloud [9]. This enables the teacher to share these tutorials with students.

```

Wolfram Language
ispitivanjeTokaFunkcije[funkcija_] := Module[{
  Print["Iskustivanje toka i crtanje grafika funkcije ", funkcija];
  DomenFunkcije[funkcija];
  Parnost[funkcija];
  Prasekaja[funkcija];
  Print[" "];
  Print["Asimptote "];
  Asimptote[funkcija, Vertical, "Vertikalna asimptota"];
  Asimptote[funkcija, Horizontal, "Horizontalna asimptota"];
  Asimptote[funkcija, Oblique, "Kosa asimptota"];
  Print[" "];
  Print["Nule i znaci funkcije"];
  NuleFunkcije[funkcija];
  Tablica[funkcija, 0.1, 0];
  Print[" "];
  Print["Intervali monotonosti i ekstrinse vrednosti"];
  Tablica[funkcija, 0.1, 1];
  Print[" "];
  Print["Konveksnost, konkavnost i pravoujne tačke"];
  Tablica[funkcija, 0.1, 2];
  Print[" "];
  Print["Grafik funkcije"];
  Plot[funkcija, {x, -20, 20}, PlotStyle -> {Blue, Dashed, Thick}, ExclusionsStyle -> {Red, Dashed, Thick},
  PointSize -> 0.01, PlotRange -> Automatic, {-5, 15}, AxesLabel -> {"x", "y"}, AxesStyle -> Arrowheads[0.0, 0.04]]];
1

```

a)

```

Wolfram Language
ispitivanjeTokaFunkcije[x^2 + x - 2] / ((x + 3)^2)
ispitivanje toka i crtanje grafika funkcije (x^2 + x - 2) / ((x + 3)^2)
Domen funkcije: x < -3 ili x > -3

Asimptote
Vertikalna asimptota: {{y -> -3, x -> -3}}
Horizontalna asimptota: {{y -> 1, x -> 1}}
Kosa asimptota: nema

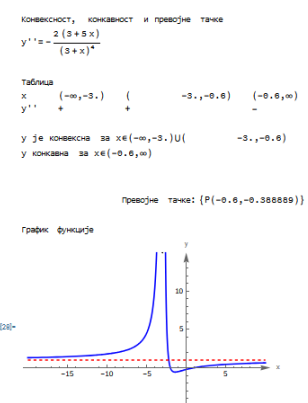
Nule i znaci funkcije
Tablica
x (-3, -2) (-2, -1) (-1, 0) (0, 1) (1, 2)
y + + + + +
uko za x ∈ (-3, -2) ∪ (-2, -1) ∪ (-1, 0) ∪ (0, 1) ∪ (1, 2)
uko za x ∈ (-2, -1)

Intervali monotonosti i ekstrinse vrednosti
y' = (2x + 1) / (x + 3)^2
Tablica
x (-3, -2) (-2, -1) (-1, 0) (0, 1) (1, 2)
y' + + + + +
uko monotono raste za x ∈ (-3, -2) ∪ (-1, 0) ∪ (1, 2)
uko monotono opada za x ∈ (-2, -1)

Nulosekusi: nema
Nulosekusi: {1, 1, 4, -0.5625}

```

b)



c)

Figure 4 – Interactive tutorial on plotting the graphics of functions

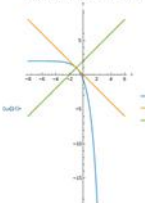
The first one is intended to support understanding the process determining the flow and plotting the graphics of functions. The tutorial is created in the form of a program that requires the desired function as input data, and as a result, prints all steps of determining the flow of the function, and then plots an

appropriate graphic of the function. The tutorial is described detailed in [10]. Figure 4a) shows a code snippet of the tutorial, and Figure 4b,c) shows the steps of determining the flow of the function $f(x) = \frac{x^2+x-2}{(x+3)^2}$, and the appropriate graphics of the function.

```
True,
tangentLine = k1 * (x - x0) + (fun /. x -> x0);
Print[Style[StringJoin[Text[{{10}}, ToString[TraditionalForm[Simplify[tangentLine]]], ".-"], FontSize -> 20,
    Spacings -> {0, 2}]]];
Pause[2];
k2 = -1/k1;
Print[Style[StringJoin[Text[{{11}}, ToString[TraditionalForm[Subscript[x, 0]]], ".-"], FontSize -> 20,
    Spacings -> {0, 2}]]];
Pause[2];
Print[Style[StringJoin[Text[{{12}}, ToString[TraditionalForm[k2]], ".-"], FontSize -> 20, Spacings -> {0, 2}]]];
Pause[2];
normalLine = k2 * (x - x0) + (fun /. x -> x0);
Print[Style[StringJoin[Text[{{13}}, ToString[TraditionalForm[Simplify[normalLine]]], ".-"], FontSize -> 20,
    Spacings -> {0, 2}]]];
legend = StringJoin[Text[{{14}}, ToString[TraditionalForm[Subscript[x, 0]]], "(", ToString[TraditionalForm[
    (x - Subscript[x, 0])]], ")] + f(", ToString[TraditionalForm[Subscript[x, 0]]], ")", text[{{20}}, "y="],
    ToString[Simplify[tangentLine]]];
legendN = StringJoin[Text[{{15}}, ToString[TraditionalForm[Subscript[x, 0]]], "(", ToString[TraditionalForm[
    (x - Subscript[x, 0])]], ")] + f(", ToString[TraditionalForm[Subscript[x, 0]]], ")", text[{{20}}, "y="],
    ToString[TraditionalForm[Simplify[normalLine]]];
gr = Plot[{fun, tangentLine, normalLine}, {x, x0 - eps, x0 + eps}, PlotLegends -> {legendf, legendN, legendN},
    AxesLabel -> {"x", "y"}, AspectRatio -> Automatic];
];
Return[gr];
Label[end];
]
```

a)

Задатак је да пронађемо једначине тангенте и нормале за функцију $f(x) = 2 - e^{x+1}$ у тачки $x_0 = -1$.
Израчунајмо најпре вредност функције у тачки $x_0 = -1$, тј. $f(-1) = 1$.
Једначина праве у тачки x_0 се рачуна по формули $y = k(x - x_0) + f(x_0)$.
При томе k представља коефицијент праве.
Коефицијент праве тангенте у тачки x_0 се рачуна по формули $k = f'(x_0)$.
Извод функције је $f'(x) = -e^{x+1}$.
Дакле, $f'(-1) = -1$.
То значи да је коефицијент праве тангенте у тачки $x_0 = -1$ једнак $k = -1$.
Једначина тангенте у тачки $x_0 = -1$ је облика: $y = -x$.
Коефицијент праве нормале у тачки x_0 се рачуна по формули $k = 1/f'(x_0)$.
Стога имамо да је $k = 1$.
Једначина нормале у тачки $x_0 = -1$ је облика: $y = x + 2$.



Legend:
 - $f(x) = 2 - e^{x+1}$
 - Tangenta: $y = -x$ (at $x_0 = -1$, $y_0 = 1$)
 - Normala: $y = x + 2$ (at $x_0 = -1$, $y_0 = 1$)

b)

Figure 5 - Animated interactive tutorial for determining equations of tangents and normals to curves

The other interactive tutorial helps students to understand the steps for determining the equations of tangent and normal lines to curves. For a given input function and the desired tangent point, the program provides a step-by-step tutorial for determining the equations of the corresponding tangent and normal lines. To make it more engaging for students, the steps are animated. In the end, the graph of the function, along with the tangent and normal lines, appears on the screen. Figure 5a) shows a code snippet from the tutorial, while Figure 5b) shows the output for the input function $f(x) = 2 - e^{x+1}$, and the tangent point $x = -1$. For more details about this tutorial, we refer to [11].

4. RESULTS AND DISCUSSION

For the purpose of the research, an appropriate survey is designed. The survey consists of ten questions, nine of them the students could answer by choosing one or more of offered alternatives, and one question was designed in purpose for giving the students the opportunity to express their own opinions and suggestions. The survey was conducted with 93 students of the Higher Education Technical School of Professional Studies in Novi Sad within the Mathematics course which runs in first semester of their studies. The students already had experiences with the digital materials (with an exception to the two aforementioned interactive tutorials written in Wolfram Mathematica – the topics covered in these tutorials have not been addressed by the time this survey was conducted), concerning that their Mathematics course is fully covered with digital materials in form of documents prepared by their professors and applications such as Google Classroom and Google Drive. Also, there were video records of tasks solutions explained step-by-step, available on Google Drive and YouTube, as seen in the previous section. The results of the survey are as follows:

1. Question: Do you like learning through online platforms?

The results of this question showed that 72% of students answered with 'Yes' to this question, while 28% of them disagrees. Such a high percentage of students which stated that they like learning through digital platforms was expected because it provides them the opportunity to follow the course more comfortably and in accordance with other obligations they have. One third of the students which disagrees are more likely the students which prefer face-to-face learning environment.

2. Question: Which platforms do you use most often?

In this question students were offered multiple platforms, and they could choose more than one. The obtained results are presented in Figure 6a).

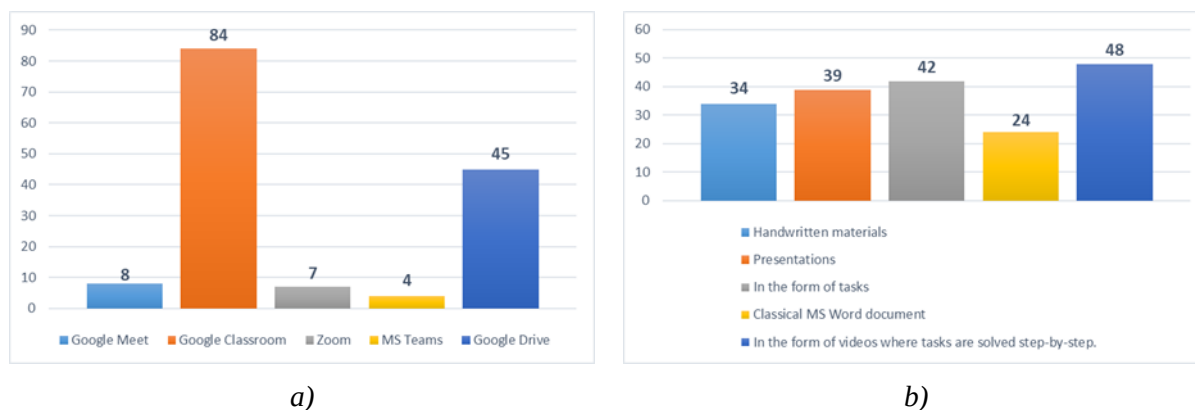


Figure 6 - Q2: Which platforms do you use most often? (a), Q4: What do you consider the most useful type of material posted?(b)

As we can see, the Google Classroom platform was the most common choice of the students, and also Google Drive. Such choices can be explained by the fact that the Mathematics course was conducted using these applications and that these applications the students find most common.

Question 3. Do you find it convenient to have instructional materials and exercises posted on Google Classroom, Google Drive (or similar online platforms)?

The students were 100% united in their opinions that they find it useful to have instructional materials and exercises posted online, as expected. The students find these materials as an additional help and reminder of previously covered material in classes.

Question 4. What do you consider the most useful type of posted material?

In question 4, the goal was to inspect the type of the digital materials students prefer. Students could make more than one choice in this question, and the distribution of their answers is given in Figure 6 (right). It can be seen that, more or less, the results were consistent. The students like the least the classical MS Word documents, which is understandable concerning that they are not used to read mathematical text because they find it too abstract. On the other hand, they prefer at most the videos where tasks are solved step-by-step, which allows them easier understanding and more efficient learning. The videos can be replayed, which is also one of the advantages contributing to adapted and individual learning.

Question 5: Is it important to you that the materials are in color?

The color of the digital materials is not so important to students, 18% of them answered 'No' to this question and even 55% says that the color is not important to them. Only 27% of students believes that the colored materials can contribute to their more efficient learning outcomes.

Question 6: Do electronic materials further motivate you to work and learn?

The results of this question are indecisive. Namely, 17% of students disagree, and 27% claims that it does not matter to them. The other half of students (56%) agree that learning materials in electronic form motivate them for learning. This results could be explained by the different modes and techniques of learning which students apply, similar as in question 5, concerning the presence of color in electronic materials.

Question 7: Is it useful for you to have test/exam preparation materials in electronic form posted on a platform?

Even 98% of students find it useful to have test/exam preparation materials in electronic form posted on the platform. This result is more than expected, since the platform allows constant access to materials and also students from remote places can use it for preparation of the test/exam.

Question 8: *Is learning mathematics more effective in person or through electronic media?*

Even 64% of students finds learning mathematics in person more effective, while only 4% does find learning through electronic media more effective. Undecided are 32% of students. These results implies that learning mathematics is still reserved for the classrooms, because the students prefer thorough explanations over materials in any form. The significant percent of undecided students implies that there is a space for using digital materials in mathematics education, but significant attention must be paid to their design in order to achieve the best results.

Question 9 : *Do you have anything to add regarding e-learning?*

This question was designed for students' suggestions regarding improving process of teaching and learning mathematics. Some of their answers were that they would like online consultations, via Google Meet or similar platforms to be organized. Also, one suggestion was to make a collection of solved mathematical problems explained step-by-step. One student expressed the opinion that all the college subjects should be followed by electronic learning materials and that this will have great benefits for students, especially for employed students.

Question 10: *Would the use of innovative models (interactive quizzes, competitions, simulations, or learning apps) contribute to your easier learning and should be included in your coursework?*

It could be said that the students recognized the benefits and advantages of electronic learning and digital materials because 62% of them expect that this kind of innovative models will contribute to their learning of mathematics. However, there are still 38% of students who think that technology can not bring improvement.

The survey conducted with the students of the Higher Education Technical School of Professional Studies in Novi Sad revealed that the majority of students appreciate the flexibility and convenience of learning through online platforms, particularly favoring video recordings that explain tasks step-by-step.

Overall, the survey results suggest in general positive acceptance of digital learning materials among students, and the specific preferences and areas for enhancement are identified. These insights can lead to the development of more effective and engaging digital resources, ultimately supporting diverse learning needs and improving educational outcomes.

5. CONCLUSION

The findings of this study emphasizes the significant impact of digital learning materials on enhancing mathematical knowledge among college students. The integration of digital platforms such as Google Classroom and Google Drive has not only improved access to educational resources but also enabled a more interactive and engaging learning experience.

The survey results indicate that students find interactive content, such as quizzes, simulations, and educational apps, particularly beneficial in maintaining their motivation and improving their learning outcomes. While traditional in-person learning continues to hold its' value, the comparative efficacy of digital learning cannot be overlooked. The flexibility and personalization offered by digital tools address individual learning styles and pace, thereby enhancing overall educational effectiveness.

However, it is crucial to address the challenges associated with digital learning, such as the need for technical support and the potential for digital fatigue. By understanding and addressing these issues, educators can create a balanced and effective learning environment that leverages the strengths of both digital and traditional methods. Future research should continue to explore the evolving landscape of digital education and its long-term implications for mathematical learning at all levels of education.

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