Challenges in Human-Computer Interaction on the Example of Photomath Mobile Application

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ABSTRACT

The article presents a study of secondary school students' use of the Photomath mobile application, which was carried out as part of a "Photomath-Digital Mathematics" educational project (Telavi Public School N5, 8th grade; pandemic time, spring 2021).

The article highlights the importance of human-computer interaction and its basic concepts, namely the usability of the Photomath app. The system was chosen as the main focus of the study. Instructions for installing Photomath on mobile devices as well as an analysis of the most important functions of the app are given. In addition, mathematical issues are also dealt with.

The phases of project design and implementation are also discussed in the article, with a focus on involving students, parents, and teachers in the project. The article demonstrates how to use the Photomath system to solve a mathematical problem, specifically how to solve two two-dimensional linear equations sequentially using the Photomath interface.

In addition, the article presents and analyzes the findings of a quantitative study conducted as part of a small educational experiment (on a five-point Likert scale) on the usability of the Photomath application from the perspectives of students, parents, and teachers.

The paper also highlights the efficacy of using the Photomath mobile app for math instruction, which was researched and validated as part of the project through the analysis of qualitative surveys (interviews with open-ended questions) conducted with students, parents, and teachers.

Based on the results of quantitative and qualitative surveys of participants, significant conclusions were drawn about the approach to using the Photomath mobile application, both in terms of software and teaching methodology.

Key Words:

Photomath Mobile Application; Human-Computer Interaction (HCI); System Usability; Experiment-Photomath-Digital Mathemathics; Attitude of students, parents and teachers

Introduction

Human-computer interaction is today dominated by touch technologies, which are both important and exciting. Their significance in everyday life is expanding to the point that nearly every modern technology is headed in this direction. Mobile phones and tablets are examples of touch technologies. They are utilized by a diverse group of people in society. There are a plethora of exciting software items compatible with touch technologies available on the Internet. Existing technological and software

solutions make it easier for people to complete jobs in any field. Touch technologies and mobile devices, which are supported by a variety of software solutions, are increasingly widely used in the field of education.

Reading characters from images has recently grown in popularity, driving the development of several technologies and programs in this area. It is important to many people (programmers) to enhance and refine it. The Photomath mobile application, which recognizes data records and, if necessary, edits them, is one of the software products we will explore in this article. It is based on OCR-optical character recognition, a technology that was created to solve mathematical problems (Scan-Solve-Learn). Many educators and scholars have complimented Photomath for its usability. At the application's official website, students, parents, and teachers have all given excellent feedback on Photomath (www.photomath.com). As a result, we became interested in integrating the program into math classes. Photomath is available for free download and installation.

The goal of this study is to look at the challenges of human-computer interaction when using the Photomath mobile application system, as well as to evaluate and analyze the program's usability for solving mathematical problems from the perspectives of students, parents, and teachers within the small project "PhotoMath - Digital Mathematics".

Methods

In order to achieve the desired goal, research based on the empirical-pedagogical experiment was carried out within the small study project "Photomath - Digital Mathematics." A heterogeneous group of eighth-graders (20 students) from the secondary school was chosen as the target group. The research was conducted as part of a mathematics class where students learned about the properties of linear functions and methods to solve a system of two-dimensional linear equations. Parents of students and teachers who were interested in Photomath were also participating in the project.

The experimental study was divided into two phases:

1) preparation of the experiment;
2) carrying out the experiment; Introduction of research methods; Analysis of research results; and draw conclusions.

The study used both quantitative and qualitative research approaches. In particular, the five-point Likert scale and open-ended interview questions were used. The study, which lasted two weeks (10 lessons), only took 10 academic hours.

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Discussion

- **About Photomath App**

Whats is Photomath - Photomath is a mobile application that utilizes a smartphone's camera to scan and recognize mathematical equations; the app then displays step-by-step explanations onscreen. It is available for free on both Android and iOS.

The app is based on a text recognition engine developed by Microblink, a company based in London and Croatia, and led by Damir Sabol, which also includes the same people who are developing both Photomath and Photoplay. The company Photomath LLC is legally registered in San Mateo, California,

and, in 2021, the company announced $23 million in Series B funding led by Menlo Ventures, with participation from GSV Ventures, Learn Capital, Cherubic Ventures and Goodwater Capital. [Photomath] [8]

Description of Photomath - Photomath uses the camera on a user's smartphone or tablet to scan and recognize a math problem. Once the problem is recognized, the app will display solving steps, sometimes in a variety of methods or multiple approaches, to explain the scanned problem step-by-step and teach users the correct process. Photomath's in-house math R&D team researches teaching methodologies from around the world, and solutions and solving steps are expert-verified.

In 2016, the app began recognizing handwriting in addition to printed text. Students can now scan textbooks, worksheets, notes, etc. [Photomath] [8]

Key Features: [Phoptomath] [9]

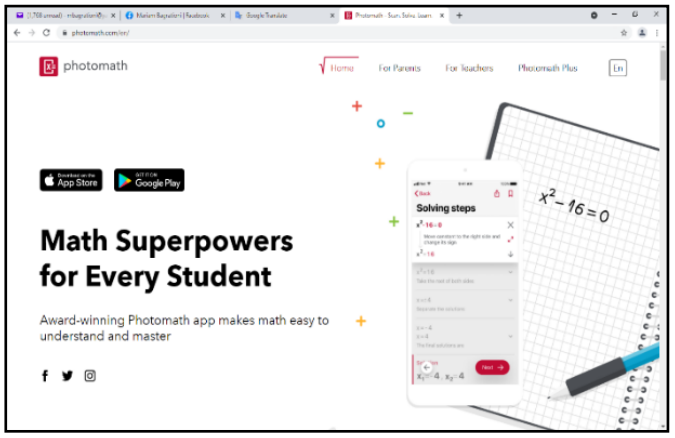
- ✓ Word problem explanations;
- ✓ Free to use;
- ✓ Step-by-step explanations for every solution;
- ✓ Exclusive how-to animations;
- ✓ Scroll through multiple solving methods per problem;
- ✓ Multi-functional scientific calculator;
- ✓ Interactive graphs.

Math Topics Covered [Phoptomath] [9]

- ✓ Basic Math/Pre-Algebra: arithmetic, integers, fractions, decimal numbers, powers, roots, factors
- ✓ Algebra: linear equations/inequalities, quadratic equations, systems of equations, logarithms, functions, matrices, graphing, polynomials
- ✓ Geometry (specific textbooks only)
- ✓ Trigonometry/Precalculus: identities, conic sections, vectors, sequences and series, logarithmic functions
- ✓ Calculus: limits, derivatives, integrals, curve sketching
- ✓ Statistics: combinations, factorials

- **Instal Photomath - Official Website**: https://photomath.com/en/

The core of Photomath is free to download. Photomath is the ultimate educational tool for a smartphone or tablet.



User Photomath

Photomath is designed for the following group of users: Schoolchildren (at least 13 years old), parents and teachers. This is also for those who are interested in mathematics.

- **About Human-Computer Interaction (HCI)**

Human-computer interaction dates back to the early 1980s. John M. Carroll is its author and founder [John M., Carrol] [7].

- ✓ **What is Human – Computer Interaction**?

Human-computer interaction (HCI) is a multidisciplinary field of study focusing on the design of computer technology and, in particular, the interaction between humans (the users) and computers. While initially concerned with computers, HCI has since expanded to cover almost all forms of information technology design. (Alan Dix and others, 2015) [1] [2]; [Theo Mandel] [11] [12]

- **About Human-computer interface (HCI)**

Human-computer interaction focuses on interfaces between humans (users) and computers. HCI researchers observe the ways humans interact with computers, and they design technologies that let humans interact with computers in novel ways. [Theo Mandel] [10] [11] [12]

What is Human-computer interface?

- **Human-Computer Interface (HCI) - is** The place where two independent systems meet and communicate. The presentation, navigation, and interaction of information between a computer system and a user. [Theo Mandel [Theo Mandel] [10]
- **Human-computer interface (HCI)** The means of communication between a human user and a computer system, referring in particular to the use of input/output devices with supporting software. Devices of increasing sophistication are becoming available to mediate the human-computer interaction. These include graphics devices, touch-sensitive devices, and voice-input devices. They have to be configured in a way that will facilitate an efficient and desirable interaction between a person and the computer. [Human Computer Interaction] [4]

- **System Usability**

What is system usability? -Usability is an important aspect when designing a human-computer interaction system. Usability refers to how efficiently and correctly a system works to accomplish specific tasks for a particular user.

- ✓ **Usability -** The ability of a product to be used in an effective and meaningful way by the intended user. [Theo Mandel] [10]
- ✓ **Usability** can be described as the capacity of a system to provide a condition for its users to perform the tasks safely, effectively, and efficiently while enjoying the experience (More efficient to use-takes less time to accomplish a particular task; Easier to learn -operation can be learned by observing the object; More satisfying to use) [Usability] [13]

Usability(user-friendly) indicators need to cover the following topics: [Jhone Brook] [5] [6]

- ✓ Effectiveness (the ability of users to complete tasks using the system, and the quality of the output of those tasks);
- ✓ Efficiency (the level of resource consumed in performing tasks);
- ✓ Satisfaction (users' subjective reactions to using the system).

- **Experiment preparation**

"Photomath - Digital Mathematics" Educational Project

We prepared the following training materials prior to the experiment: The official website (https://www.photomath.com/en/) instructions on how to use Photomath; A series of problems from the

eighth-grade math textbook [Gogishvili G., and all., 2020] [3] to learn the properties of linear functions and develop strategies for solving systems of two-dimensional linear equations over the project implementation time given. Photomath app was installed on my phone for convenience. (See Figures N1-N9)

Figure N1 - Photomath icon is displayed on mobile phone screen after app installation;
Figure N2 - Photomath work window;
Figure 3 - Scanning a math problem;
Figure N4 - Selecting the solution method;
Figure N5 - Solution of a system of two linear two-dimensional equations by subtraction;
Figure N6 - Solution of a system of two linear two-dimensional equations by summation;
Figure N7 Graphic solution of a system of two linear two-dimensional equations;
Figure N8 - Edit mode;
Figure N9 - Using advanced features.

Figure 1 Photomath icon

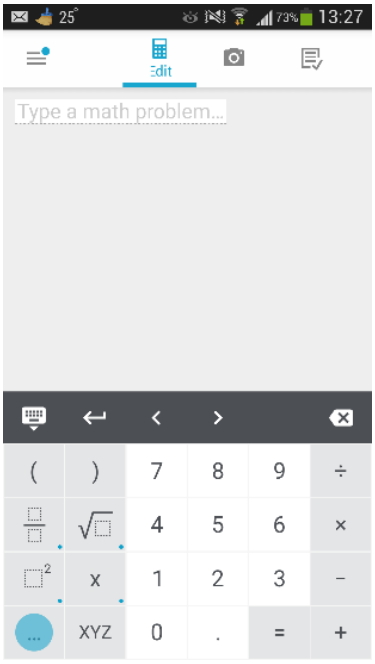


Figure 2 Photomath work window

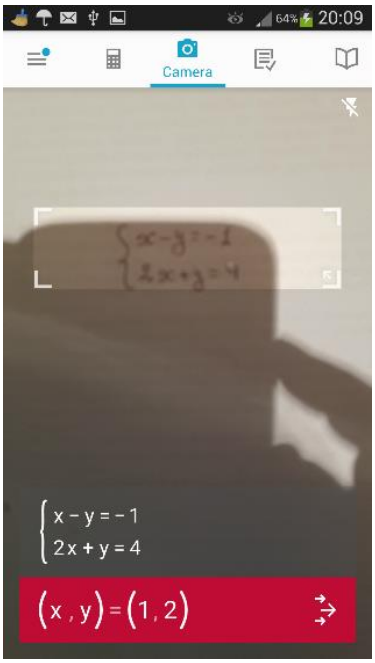
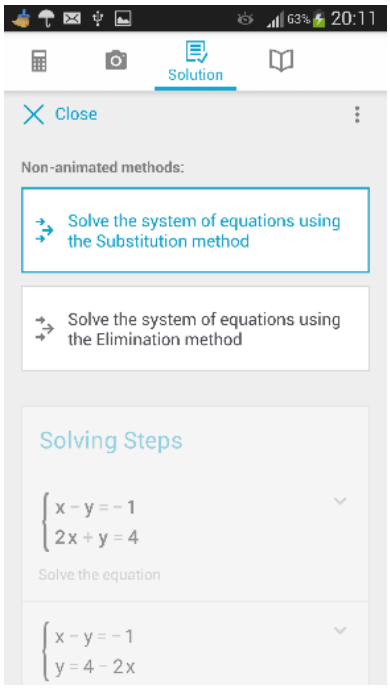
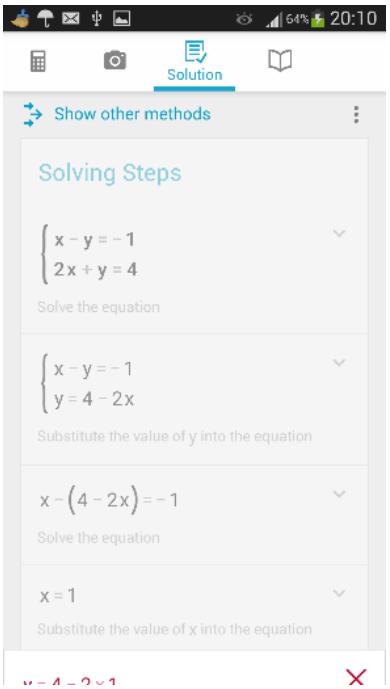


Figure 3 Scanning a math problem;;





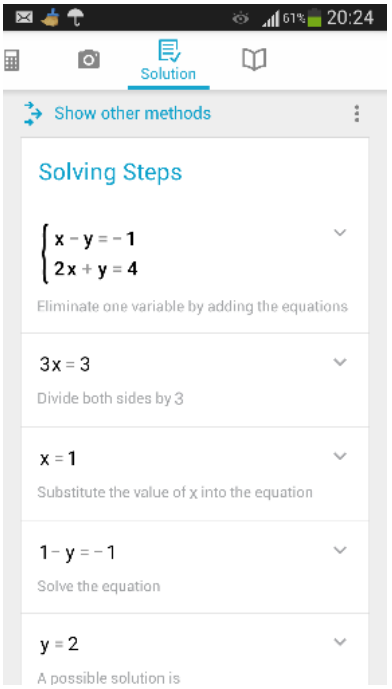
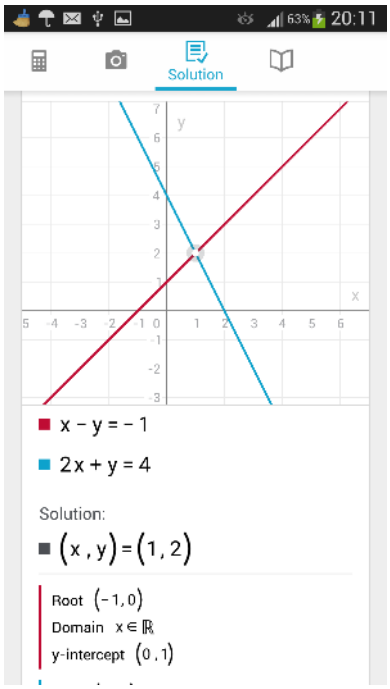
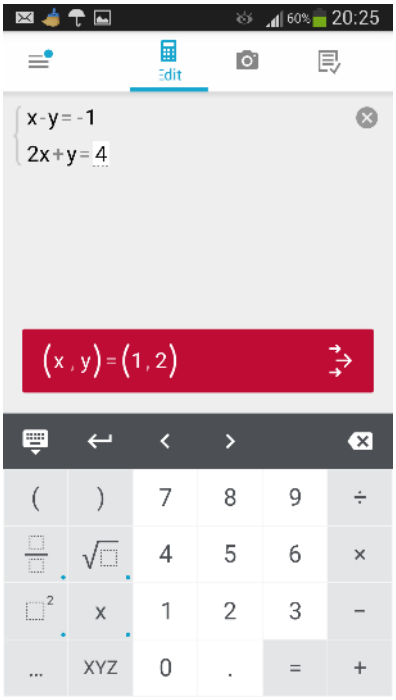


Figure 4 Selecting the solution method; *Figure 5 – Solution by subtraction* *Figure 6 Solution by summation*





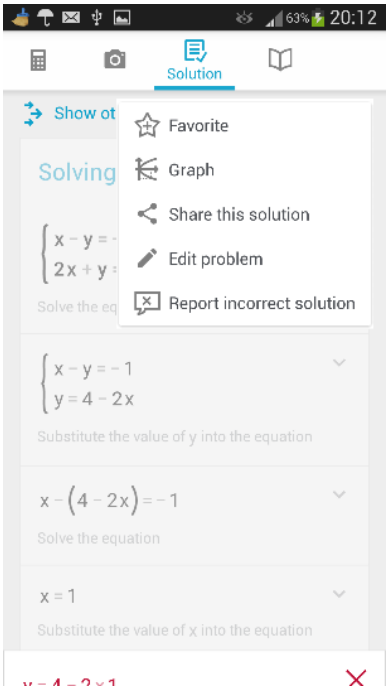


Figure 7 Graphic solution *Figure 8 Edit mode;* *Figure 9 Using advanced features*

- **Experiment Implementation**

1) As part of the project, students were introduced to the Photomath mobile app and its features; in particular, we gave them information on the program's operation from the official website; they were also shown the software's visual element and encouraged to utilize it to solve mathematical problems.
2) The Photomath program was installed on the students' mobile devices (phones and tablets).

3) Students were instructed to use the following sequential steps to solve a mathematical problem based on easy exercises:
   - ✓ create mathematical notes on a sheet of paper, scan an image in the Photomath work window with a mobile phone camera - optical recognition of the recording;
   - ✓ Edit, delete or rescan the screen recording if there is an issue;
   - ✓ A step-by-step overview of Photomath's process for solving mathematical problems.
4) Students were asked to compare and contrast the process of solving arithmetic problems at home using traditional and recently learned digital methods and to share their views with us in the next lesson.
5) Students and their parents were tasked with overseeing the usability of the Photomath mobile app while students work on their homework independently.
6) At the end of the experiment, children and their parents completed an anonymous Likert scale survey and interviews with open-ended questions. Teachers interested in the Photomath mobile app system were also asked to participate in a survey.

- **The study findings**

The research looked at how students, parents, and teachers felt about Photomath. The Photomath system's efficacy in math classes was investigated using both quantitative and qualitative research methodologies.

✓ **Quantitative research results -** The quantitative questionnaire was presented using the Likert scale model. It comprised three criteria for assessing system usability in general: Effectiveness; Efficiency; Satisfaction [John Brooke] [5] [6]), which was to be rated on a five-point scale: (Strongly disagree; disagree; neither agree nor disagree; agree; strongly agree). (See Figure N10 - Survey Form)

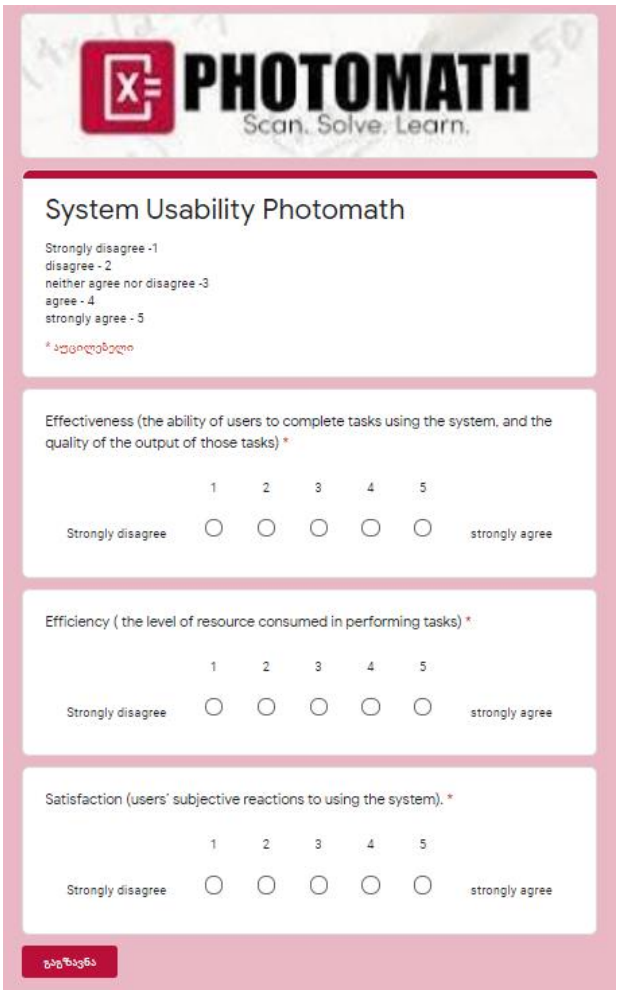


Figure 10 Survey Form

The quantitative research yielded wonderful results. The usability criteria of the Photomath mobile application were given a high score by the project participants, as shown in the table, indicating the app's success. Participants' estimates may, however, be inaccurate in some cases (See Table N1 - Usability Criteria Assessment).

Table N1 - Usability Criteria Assessment

Indicators for usability criteria	**Evaluation of criteria for the usability requirement**		
	Student	**Parent**	**Teacher**
Effectiveness (the ability of users to complete tasks using the system, and the quality of the output of those tasks)	High	High	High
Efficiency (the level of resource consumed in performing tasks)	High	High	High
Satisfaction (users' subjective reactions to using the system)	High	High	High

✓ Qualitative Research Results

In order to better understand the project participants' interaction with Photomath, we were interested in their candid thoughts. In the form of interviews, we performed a survey. The major questions were: How would you rate the usability of the Photomath mobile application? How would you rate your connection with Photomath in terms of solving math problems?

Students demonstrated in their interviews that they are comfortable using the Photomath mobile app and that the user interface is simple to grasp. To answer a math issue, they only had to run a few commands. Most importantly, the app carried students through the exercise process step by step and provided thorough feedback on various techniques for completing arithmetic problems. They could re-scan, edit using a standard and mathematical keyboard, delete the object at will, and modify the way of solving mathematical problems with the application.

As can be seen, this approach makes it easier for students to solve and comprehend mathematical issues, which is crucial for mathematics education success. They can complete their homework on their own in the following lesson. The Photomath software becomes their devoted companion. There is no more anxiousness (worries) in class. Solving systems of two-linear equations turns out to be relatively simple.

The parents' views about the Photomath app were fascinating. They found the application to be a trustworthy companion. They recall that they were frequently unable to assist their children in solving arithmetic issues and that it was difficult for them to devise the optimal method for solving math problems and communicating them to children in an understandable manner. Furthermore, because they had mastered math ideas a decade ago and were therefore unfamiliar with new approaches to learning, the majority of them were unable to assess how effectively their children handled math issues. They may now easily assist their children as the Photomath user interface is simple to utilize and explains the problem-solving procedure step-by-step**.** As a result, their children are content and joyful because the program instils confidence (persuasiveness) in them when it comes to mathematics. Another benefit of the program, according to them, is that the app does not require the internet to function. Photomath is the perfect partner for parents because of all of the above.

Teachers' perspectives on Photomath were particularly interesting. They stated that they would definitely recommend this program to their students for a variety of reasons, including deepening topics gained in class, checking homework, and speeding up individual learning.

Summing up, the software functions similarly to a calculator in that students can only view the final answer to a math problem (answers to the problems can also be found at the end of the book). Photomath, on the other hand, presents a step-by-step solution to the problem. It teaches students how to solve mathematical equations correctly and consistently, allowing them to better comprehend mathematical issues that have been understudied in class due to lack of attention. As a result, proper application of the program might be extremely beneficial. The software teaches the user new problem-solving skills that would not be covered in a traditional course. This opens up a lot of possibilities for mastering mathematical concepts (Scan-Solve-

Learn).

The program has a user-friendly UI. It allows students to send the app both handwritten and printed math problems, as well as complete assignments using a standard or a math keyboard. It can handle both arithmetic calculations and graphical representations of functional connections. In general, survey participants said the app was a valuable tool because it allowed students to complete their homework independently.

In addition to its benefits, project participants highlighted the program's shortcomings in the surveys. They discovered that the program couldn't recognize or grasp the textual content of mathematical problems in particular. On the screen, there is no handwriting technology, and the Georgian language is not supported.

Summary

The Photomath mobile application has been successfully used in math lessons based on the analysis of the research data. The survey results backed up the project participants' positive feelings about Photomath. The majority of participants agreed that the Photomath system was easy to utilize in math class. However, they pointed out some flaws in the system. They recommend that the system's design be improved for usability. The following key results were obtained after analyzing data from quantitative and qualitative studies:

1. The study findings revealed that the Photomath system's usability (human-computer interaction) makes it straightforward for anyone to solve math problems.
2. Student feedback showed that the Photomath system completely changed their attitude towards mathematics. Their persuasiveness and motivation are enhanced by the software.
3. The parents' perspectives demonstrate that thanks to the Photomath technology, they can now assist their children in solving math problems as experts;
4. According to the teachers who participated in the study, the Photomath system is good for individual student work, for example, for self-study at home. However, they believe that this should be based on proper, targeted use of the system- Scan, Solve, Learn- because there is a risk that students will just use Photomath in calculator mode to find the final answer to the math problem.
5. The Photomath system was found to have the following shortcomings: Math word problems are incomprehensible to the system; there is no pen or handwriting function on the app's operating screen; In addition, the Georgian language is not supported. We hope that the programmers take this into account and that Photomath will incorporate these functionalities soon.

Conclusion

The survey results supported the project participants (students, parents, and teachers) favourable attitudes to Photomath application. They did, however, point out several faults in the system. They recommended that the system be implemented in the learning process, but they also emphasized the potential drawbacks.

Overall, the following significant conclusions were established based on quantitative and qualitative research:

1. The study's key finding was that the project participants were able to interact with the Photomath

system without difficulty, which was attributed to the app's usability. Furthermore, thanks to the Potomath app, student participation in the learning process rose. This is supported by a review of quantitative and qualitative research findings, as well as our observations.

2. Using the Photomath system is an innovative and effective approach to maths teaching. Teachers can use the application system to build a more flexible learning environment than they could in the past. The enthusiasm and persuasiveness of students to study mathematics has increased through the use of this system; Cooperation between students and parents has improved, as have the technological skills of those involved in the project and the level of knowledge of the students. Even if the students initially had difficulty solving a math problem with the Photomath system, at the end of the project everyone was actively interested and adept. Students struggling with math found the approach particularly helpful. Using the Photomath program, their learning outcomes and the quality of their schoolwork have improved.
3. Some potential drawbacks of adopting the Photomath method is that students may lose interest in doing their schoolwork independently, that the software may drive them to become lazy, and that they may use technology for non-educational purposes.

The study was the first of its kind, and it was done in a classroom with a small target group. We expect to use mobile applications in math classes on a larger scale in the future to carry out additional research and synthesize the findings. The practice can be adapted to different classes.

In the end, the project was crucial because it combined Photomath, OCR (optical character recognition), and mathematics, yielding highly successful results. Learning with the aid of mobile devices, I believe, will become a part of my teaching culture and practice.

Acknowledgements

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