2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33986

Revising College Algebra Instruction to Accept and Incorporate the Use of Smart Phone Applications

Dr. Zeynep Akcay Ozkan, City University of New York, Queensborough Community College

Dr. Zeynep Akcay Ozkan is an Assistant Professor of Mathematics at Queensborough Community College of the City University of New York. She received her PhD in Applied Mathematics from the joint program at New Jersey Institute of Technology and Rutgers Universities (2014), with concentration on Mathematical and Computational Neuroscience. She also holds an MS degree in Financial Mathematics from Florida State University (2009). Dr. Akcay Ozkan's research interests include Online Teaching of Mathematics. She has completed several workshops on online teaching since 2016. She mentors faculty members as they develop their online or partially online courses and assesses their courses with the Quality Matters Rubric. She has served in the eLearning Committee of the college in chair and secretary positions. She is a member of the Math Department's Best Practices in Teaching and Learning Committee since 2017, and served in chair and secretary positions.

Dr. Dona Boccio, City University of New York, Queensborough Community College

Dr. Dona Boccio has a Ph.D. in Mathematics from the City University of New York Graduate Center, and an M.S. in Mathematics from New York University - Courant Institute of Mathematical Sciences. She has taught mathematics at Queensborough Community College since 1980.

Dr. Boccio was a recipient of the American Mathematical Association of Two-Year Colleges (AMATYC) Teaching Excellence Award in 2017. She also received the 2005 Award for Outstanding Contributions to Mathematics Education from the New York State Mathematics Association of Two-Year Colleges (NYSMATYC).

She was a Faculty Fellow in the 1998 and 2001 NASA-ASEE Summer Faculty Fellowship Programs, the 2002 NASA Faculty Fellowship Program, and then spent a sabbatical year at NASA-Marshall Space Flight Center. Her research included tracking orbital debris and modeling atmospheric pressure on Mars.

Dr. Boccio frequently collaborates with faculty from other departments on grants, pedagogical research, and course design. She has mentored numerous faculty from outside her department in the eLearning program.

Dr. Dugwon Seo, City University of New York, Queensborough Community College

Dr. Dugwon Seo is an assistant professor in the Engineering Technology Department at Queensborough Community College. Dr. Seo has been teaching engineering technology courses including digital circuit, computer applications, computer-aided analysis, and renewable energy. Her research interest includes various renewable energy, digital circuit system, remote sensing, and technology education.

Dr. Sirin Budak, Univeristy of Wisconsin-Stevens Point

She is an associate professor of mathematics education at the University of Wisconsin–Stevens Point. Her research area includes representations, visualization, and the effect of technology in learning.

Revising College Algebra Instruction to Accept and Incorporate The Use of Smart Phone Applications

Abstract

The unavoidable transition to online education due to Covid-19 pandemic has impacted instruction at all grades and in all subject areas, including college level Mathematics courses. One of the issues that has been faced is the inability to proctor exams properly. Calculators with Computer Algebra Systems and their corresponding smart phone applications can provide not only answers to most problems, but they also provide solution steps. Mathematics departments at many institutions have established policies which regulated the use of calculators and smart phones in lectures and exams. However, lack of proper proctoring in online courses makes it possible for students to pass a course, even with a decent grade, without learning the concepts. On the other hand, as the use of computers became more common, many skills previously considered as required are not required anymore, such as learning how to use logarithmic tables to evaluate logarithms. In this study, we first demonstrate the capabilities of smart phone applications and provide tips for writing procedural problems that are not easily solvable by these apps. We show examples of problems that are solvable by the apps and suggestions to revise them. Second, we discuss general suggestions on how to revise the College Algebra instruction, especially for engineering students. Our suggestions aim to fill in the gaps that could potentially be created when these apps are commonly used among students. In summary, we review and revise College Algebra instruction and assessments to accept and incorporate the use of smart phone applications. Revised topics, together with effective assessment strategies will potentially improve learning outcomes, especially when the course is taught online. Our work concentrates on revision of College Algebra topics for Engineering students, but our strategy can be applied to revise other mathematics topics for any major.

Keywords: Online teaching, Phone applications, college algebra, instruction strategies, assessment methods

Introduction

The unavoidable transition to online education due to COVID-19 pandemic has impacted instruction at all grades and in all subject areas [1]–[3]. Some of these impacts are expected to fade out when the pandemic is over and normalcy is restored. However, it is also expected that there are going to be long term impacts of this online instruction period in higher education.

Challenges with this rapid transition to online teaching of mathematics have been discussed extensively worldwide [4]–[8]. Students and instructors have been largely dissatisfied with this mandatory change [9] and have expressed preference in face-to-face learning [10]. Delivering the course content to students in a virtual environment is not easy [5]. However, assessing student learning when teaching online is even more difficult and requires detailed planning [11]. The existence of plentiful online resources makes it very difficult to assess student knowledge, especially for the current curriculum. Among the changes suggested to adapt to the new normal, revision of curriculum has been brought up [12]. In this article, we concentrate on students' improper use of smart phone applications which can solve mathematical problems. Our aim is to contribute in restructuring College Algebra instruction and assessments, to maximize student learning with the existence of these applications in the new normal.

Use of Smart Phone Applications in Teaching of Mathematics

Some of the commonly used smart phone apps that can solve mathematical problems are Photomath, FastMath and Cymath. With the use of these apps, it is possible to obtain the solution steps of a standard College Algebra problem in seconds by taking its picture. Hence, it is possible for a student to submit the correct solution to a problem without having any understanding of it. Therefore, instructors should be aware of the existence of these applications and their capabilities to design the students' learning assessments accordingly.

The use of smart phone applications in mathematics instruction has been discussed widely [13]–[16]. Available applications have been introduced with their benefits and drawbacks with divergent opinions on the use of them. In a study which introduces Photomath together with Desmos and Geogebra, the main problem with using Photomath is emphasized as "it may harm the students' task of independent drilling" [17]. On the other hand, one of the studies which explored the use of Photomath among middle school students in Malaysia concluded that it enhanced the learning of algebraic equations [18]. Based on this, they concluded that "Photomath application encourages students in the 21st century of learning and it is preferable for the student to add on Photomath in classroom learning". In other studies, math instructors' attitudes towards use of Photomath were mostly positive [19], [20]. The statement "I think that teaching math problem solving using photo math will improve students' achievement levels." was mostly agreed by 127 teachers [20]. Wali and Omaid concluded that instructors believed more in the benefits of smart phone use in classes than its barriers [19]. In this study, the average level of agreement to the statement "it provides anywhere any time learning opportunity" was found to be significantly higher than the average level of agreement to the statement that "cheating was a barrier" for smart phone use in classroom.

The studies agree on the frequent use of technology by students as an aid in completing their assignments while they have different findings on students' perceptions about the use of this technology [21], [22]. A survey administered to 224 university students in United Arab Emirates found that while 37.5 percent of the surveyed students accepted cheating among friends, 78 percent accepted cheating using technology, which included mostly hand held devices such as mobile phones and programmable calculators [22]. On the other hand, in an interview on students' use of technology in math classes at a university in the United States, none of the students believed that they were plagiarizing [21].

There have been some studies on how to revise instruction and assessments to make better use of these technologies [21], [23]–[26]. An early study towards this aim after the initial release of Photomath (2014) discusses concerns with the use of this app and ways to respond to it [23]. The three ways to respond were to "ban access, restrict access or consider a different division of labor". Our work targets the last scenario, as we suggest revisions to instructions and assessments which will create alternative tasks for students. It is advised, in another study, that teachers should stop fighting with the available technology, accept them and find ways to use them for students' advantage [24].

A study which explores ways to "use technology to enhance and/or transform assessment as, for, and of learning" bases their ideas on the SAMR (Substitution, Augmentation, Modification, and Redefinition) model, which is a framework that categorizes how technology can be incorporated in the classrooms [27], and invites other researchers to "explore more specific ideas for using technology in assessment of learning" [25]. Another recent study suggests designing assessment criteria and innovative assessment tasks that help students understand the learning outcomes expected from them [21]. And lastly, George invites researchers to "figure this out together, brainstorm, fail, succeed, and learn from each other" [26]. We accept this invitation and aim to contribute to this effort. Some methods similar to the ones we discuss in this paper have also been brought up by other researchers in presentations or forums [28], [29]. However, our literature review has not revealed any published study on this issue. Therefore, this study also serves as a compilation for these ideas.

Outline of the Paper

Our study explores ideas to revise College Algebra instruction and assessments, to improve student understanding of mathematical concepts given their use of smart phone apps. We categorize the problems in College Algebra as conceptual, procedural and application problems. Most of the conceptual and application problems are not immediately solvable by these applications. However, most procedural problems can easily be solved by these applications. Allowing students to solve procedural problems by apps, eliminating these problems altogether from assessments and assessing student knowledge only through conceptual and application problems could be an approach, at least for some topics. However, it might be desirable for students to understand the procedural problem; what it means and how it is solved.

In Section 1, we demonstrate the capabilities of smart phone apps and provide tips for writing procedural problems that are not easily solvable by these apps. We show examples of problems that are solvable by the apps and suggestions to revise them. In Section 2, we discuss general suggestions on how to revise the College Algebra instruction, especially for engineering students. Our suggestions aim to fill in the gaps that could potentially be created when these apps are commonly used among students.

We choose Photomath to provide sample solutions and to test the effectiveness of our strategies. However, we expect to receive similar results with the other apps and encourage instructors to further explore them.

Section 1. Writing Procedural Problems in the Existence of Smart Phone Apps

In this section, we discuss tips to rewrite procedural College Algebra problems to minimize use of smart phone apps by students and maximize their learning of mathematical concepts. We provide sample procedural problems that can be solved by these apps and suggest tips for revising these problems.

Tip 1. Write questions in words and let students rewrite them in mathematical notation.

This method forces students to take an extra step to write the question in mathematical language. It promotes critical thinking and prevents immediate use of phone applications.

<u>Standard Problem 1:</u> Multiply $(5 - 3i)(5 + 3i)$.

This problem can easily be solved with the phone applications (Figure 1A). Students do not even need to read or understand what is being asked in the question.

<u>Revised Problem 1a:</u> Multiply $(5 - 3i)$ and $(5 + 3i)$.

When the problem is asked in this way, Photomath does not provide the answer (Figure 1B) and students would need to rewrite the problem in mathematical language before being able to use the application. This would help improve their understanding of mathematical notation and contribute to their mathematical literacy.

<u>Revised Problem 1b:</u> Multiply $(5 - 3i)$ with its conjugate.

When the problem is asked in this way, Photomath does not provide the answer (Figure 1C) and students would first need to find the conjugate of the given complex number before writing the multiplication in mathematical notation. Asking it this way would also assess their knowledge on the definition of conjugate.

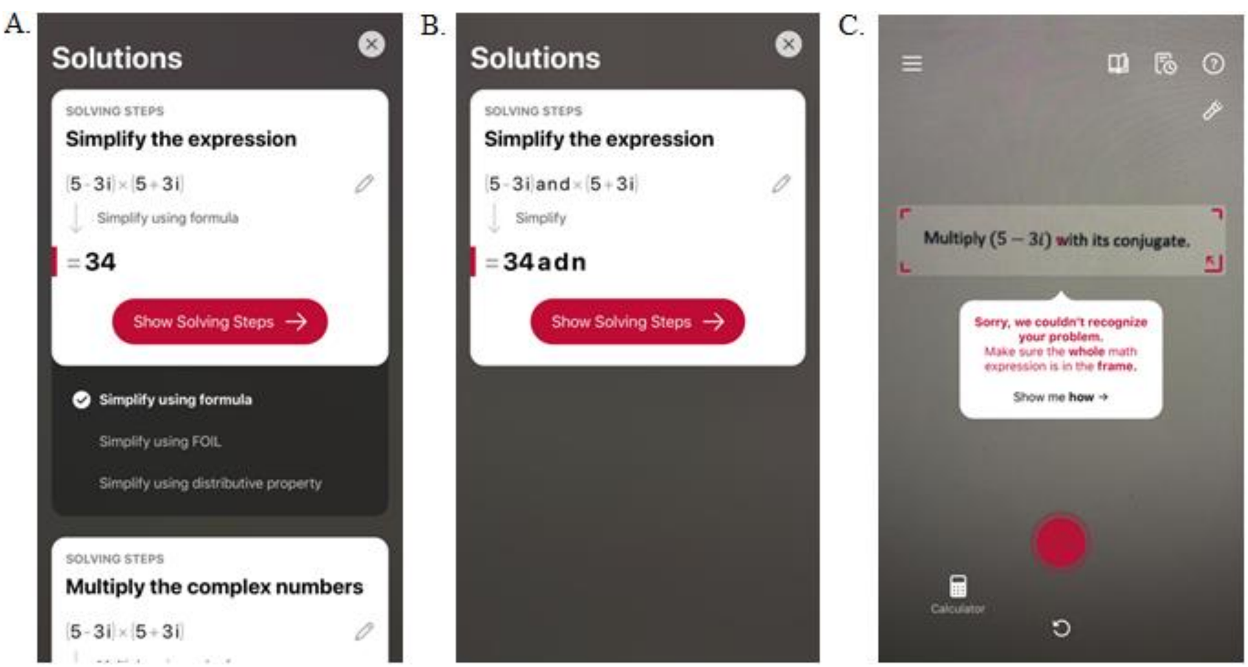


Figure 1. Screenshots of the Photomath application when it is used for solving Standard Problem 1 (Figure 1A), Revised Problem 1a (Figure 1B) and Revised Problem 1b (Figure 1C).

Tip 2. Ask students to solve a problem in a specific order of steps.

In most problems, there is more than one way that takes one to the correct answer. Most instructors may normally accept all valid ways that yield a correct answer. However, for the purpose of eliminating or minimizing the use of apps, they may consider requiring students solve a problem in a specific way, different than the way provided by the common phone apps. For example, when solving rational equations, Photomath first collects all rational expressions on one side of the equation. Students can be asked to start the problem by finding the least common denominator and eliminating the denominators before they collect all terms on the same side. This will also help them identify the steps that takes them to the correct solution and understand the purpose of each.

Tip 3. Use symbols instead of variables in equations or functions.

Standard Problem 2: Let x and y be variables that represent positive numbers. Rewrite with rational exponents and simplify:

$$\sqrt[3]{125\, x^9 y^6}$$

Revised Problem 2: Let ☐ and ✶ be variables that represent positive numbers. Rewrite with rational exponents and simplify:

$$\sqrt[3]{125\, \square^9 \bigstar^6}$$

The phone apps can provide the correct answer to the standard problem but not to the revised problem. In some cases, when the app does not recognize the symbol, it cannot provide a solution and an error message is displayed as in Figure 1C. In this specific revised problem, the app misunderstands the problem and provides an incorrect solution. If the student is knowledgeable enough not to directly copy this incorrect solution and works around by rewriting the question in the standard form, they can achieve the correct answer through the app. However, we expect this extra step to still contribute to their understanding of the notation.

A. B.

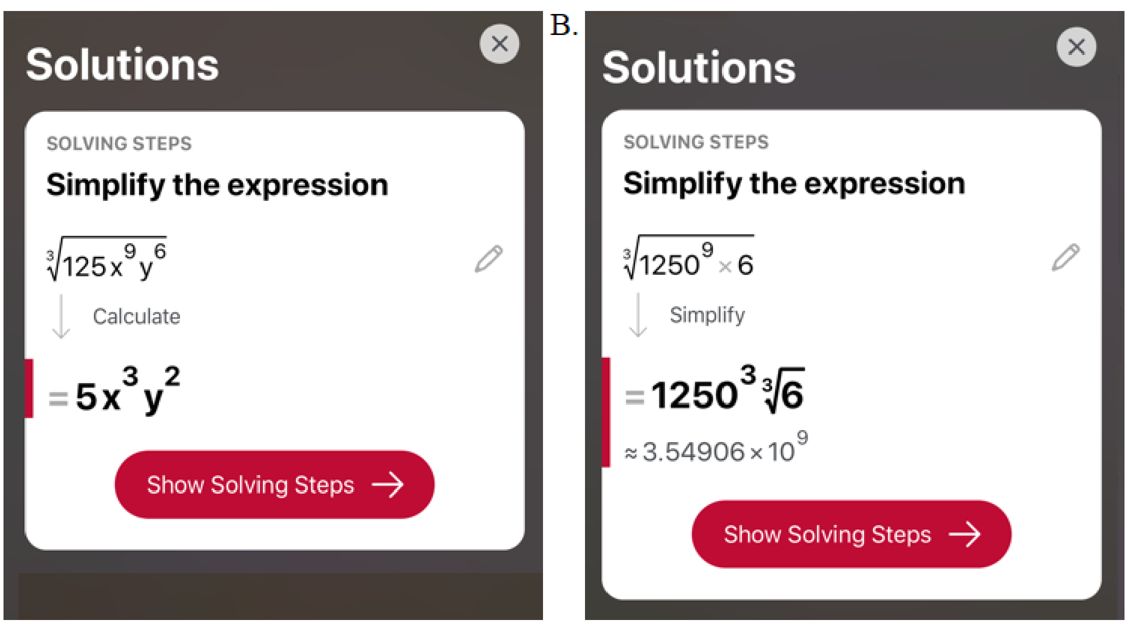


Figure 2. Screenshots of the Photomath application when it is used for solving Standard Problem 2 (Figure 2A) and Revised Problem 2 (Figure 2B).

Tip 4. Ask reverse questions.

Standard Problem 3: What is the domain of the rational function $\frac{2x+1}{x^2-9}$?

Revised Problem 3a: The domain of a rational function does not include 3 and -3. What could be the denominator of this function?

Instead of providing the students the rational function and asking its domain, which can immediately be answered by the phone apps when the function's image is captured, instructors may give them the domain and ask students to write the denominator of the function.

Tip 5. Provide the answer to the question and ask for detailed explanations in words.

If it is not possible to revise the question to minimize the use of apps, instructors may consider providing the answer to the students and asking them the reasoning behind that answer. This reminds the students that writing only the answer will not provide them any credit. Most apps also have explanations for the majority of topics, but the students will at least be forced to read them as they copy. Here is a sample question:

Revised Problem 3b: Why do we exclude 3 and -3 from the domain of the rational function $\frac{2x+1}{x^2-9}$?

Section 2. Revising College Algebra instruction for engineering students

In this section, we discuss some tips to revise College Algebra instruction, especially for students in the engineering and technology disciplines. The aim of these revisions is to help students develop critical and mathematical thinking skills that are required in engineering and technology fields given that the student has access to phone applications and other technology aids for mathematical problems.

Suggestion 1. Support students to acquire general math knowledge.

There are plentiful resources that do the calculation for students. However, to be able to properly make use of these tools for their needs, students should understand the mathematical language and identify what they work with. An example could be from rational expressions. When students are asked to "simplify a rational expression" or to "rationalize a denominator", they can do this immediately with the use of apps. However, students should also understand the terminology, what does "rationalizing the denominator" mean, and they need to know the purpose of doing this task. For this purpose, questions designed to help support students mathematics literacy will be beneficial in the assessments. Here are two sample questions.

Sample problem 1: What does "rationalizing the denominator" mean? Explain with your own words.

Sample problem 2: What is the purpose of multiplying a denominator with its conjugate? Explain with your own words.

Suggestion 2. Ask simple conceptual questions to motivate critical thinking.

We choose the topic of absolute value equations to carry this discussion. Standard college algebra textbooks include problems similar to the one below:

Standard problem 4. Find the solution set of the equation. Check each solution.

$$|2x+8|+3=15$$

When the Photomath app is used, the solution to the above equation is provided immediately. Instead of asking this procedural problem, conceptual problems which cannot be solved by phone apps could be preferred. Here are two suggestions.

Revised problem 4a. Find the numbers whose absolute value equals 7.

Revised problem 4b. The distance from $2x$ to 30 is 10. What is x?

Although the equations that rise from the revised problems are simpler than the equation in the standard problem, these alternative problems could add more to students understanding of the absolute value concept.

Suggestion 3. Ask more application problems

Application problems could be made the core of each topic. Often application problems are left to the end of each section and little or no time is allocated for application problems. Starting each section by an application problem could help students give meaning to the mathematical topic they are studying and prepare them to translating word problems into mathematical language. Here is an application problem which could be used in absolute value equations.

Application problem. Emily lives on the 23rd street and Camila lives 5 streets away from her. Write an absolute value equation to find on what street Camila could be living?

Suggestion 4. Make connection between topics by unifying themes

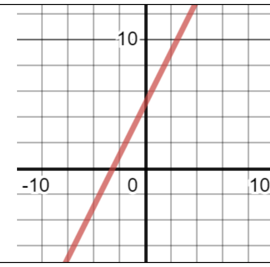
The concept of a function is a unifying theme for College Algebra topics. An idea is to create a table in the beginning of semester, with the functions that are to be covered during the class listed in separate rows, and several properties of functions listed on the columns. Students can expect what to learn before they start the class and can fill the table as they go along the semester. Such a table, an overview of the topics covered, can help them make connection between the topics covered.

A similar table that categorizes different number systems (Rational, Irrational, Complex etc.) and corresponding set notations (for discrete vs continuous) could also be provided to students. These tables could be referred often during the semester to help them make connection between topics and have a general understanding of the course.

Suggestion 5. Include literal equations in each topic

One of the mathematical skill that engineering students need to have is to be able to use formulas properly. This skill includes understanding the relation between multiple variables in a formula.

Table 1. Sample table to help students make connections between different functions covered in the course.

Name	Example	Domain	Range	Sample Equation	Graph
Linear Function	$f(x) = 2x + 5$	All Real Numbers	All Real Numbers	$2x + 5 = 9$	
Quadratic Function					
Rational Function					
Radical Function					
Exponential Function					
Logarithmic Function					

This relation can usually be understood by solving a formula for a specific variable. In College Algebra, this is mainly covered under the Literal Equations title. A formula or a literal equation may include all types of functions that are covered in College Algebra classes. Therefore, it could be considered as a unifying topic for the class.

Literal Equation Problem: The ideal gas law relates the pressure P (pascal), volume V (m^3), absolute temperature T (Kelvin), and amount of gas n (moles). The law is

$$P = \frac{nRT}{V}$$

where R is the gas constant.

An engineer must design a large natural gas storage tank to be expandable to maintain the pressure constant at 2.2 atmospheres. In December when the temperature is 4°F, the volume of gas in the tank is 28,500 ft^3. What will the volume of the same quantity of gas be in July when the temperature is 88°F [30]?

The latest available version of Photomath (as of March 2021) is not capable of solving a formula for a specific variable. An error message as in Figure 1C shows when the app is used for the formula in the above problem. Therefore, this type of problem is a great candidate to include in an assessment. Usually, this topic is covered as a separate section in College Algebra classes and not a lot of time is allocated. We suggest to include a literal equation type of problem after each function topic is covered.

Suggestion 6. Accept and integrate use of smart phone apps for relevant problems

It is essential for new generation learners to utilize digital tools to solve problems as technology continues to change and evolve. Qualification of professions in engineering and technology fields nowadays demands fast adaptation to the new technology and the ability of using digital tools to find relevant information and solve problems in addition to strong mathematical background. An introduction to smart phone apps by the instructors could help students make use of these tools efficiently. The instructor could demonstrate the use of these tools in some problems, express his/her appreciation towards the available technology and how it makes our lives easier and support the use of the tools by students where possible. An example could be to show how the smart phone apps perform simplifying complex fractions in a second, a tedious process which can normally take minutes.

Conclusions and Discussion

It has always been a challenge to balance the use of technology by students. Mathematical concepts build on top of each other and make the basis for many other disciplines. Inappropriate use of technology in mathematics classes could prevent students from establishing a solid mathematical background. On the other hand, avoiding the use of technology altogether in mathematics classes is also inefficient. As new technology is available, mathematics teaching should be adapted accordingly. Many of us might have only heard of logarithmic tables and seen one when reading history of mathematics. However, it is not hard to imagine college students being taught and assessed on the use of logarithmic tables before computers were being commonly used [31]. By not learning how to read logarithmic tables, have we lost a skill? Have using calculators for evaluating logarithms prevented us from forming a solid mathematical background or from better understanding other mathematical concepts? If not, can we assume that, by using smart phone apps, College Algebra students will not lose any skills that they will need in their future studies?

In this study, we provided some tips to rewrite assessment questions which are not immediately solvable by the smart phone apps and suggestions to revise instruction in college algebra classes. However, it should be remembered that the apps continually improve and evolve, and instructors should follow their progress to be able to adjust their teaching methods accordingly. This should motivate the researchers to continue having conversations on this topic.

When exam proctoring is possible, the decision on what technology is allowed and what is not, is made by the instructors or the institutions. It is easier to design assessments when there is control over what technology students benefit from. However, the transition to online teaching due to the Covid-19 pandemic gave rise to the problems with accurate assessments. Most of current math instruction and assessments have been designed to be taught in person with proctored testing. The possibility of abusing the technology by students hasn't been addressed much yet. This problem naturally occurred with the inevitable transition to online teaching. Absence of proper exam proctoring in online teaching forced instructors to review the use of technology in mathematics classes and redesign their classes accordingly. However, the challenge of adapting math instruction to available technology has existed before the online transition due to pandemic and it will continue to exist even after it is over.

References

[1] A. C. Carius, “Teaching Practices in Mathematics During COVID-19 Pandemic: Challenges for Technological Inclusion in a Rural Brazilian School,” *Am. Sci. Res. J. Eng. Technol. Sci.*, 2020.

[2] A. Khirwadkar, S. Ibrahim Khan, J. Mgombelo, S. Ratkovic, and W. Forbes, “Reimagining Mathematics Education During the COVID-19 Pandemic,” *Brock Educ. J.*, 2020, doi: 10.26522/brocked.v29i2.839.

[3] E. M. Mulenga and J. M. Marbán, “Is covid-19 the gateway for digital learning in mathematics education?,” *Contemp. Educ. Technol.*, 2020, doi: 10.30935/cedtech/7949.

[4] J. König, D. J. Jäger-Biela, and N. Glutsch, “Adapting to online teaching during COVID-19 school closure: teacher education and teacher competence effects among early career teachers in Germany,” *Eur. J. Teach. Educ.*, 2020, doi: 10.1080/02619768.2020.1809650.

[5] Sabaruddin, Marzuki, and Khairunnisak, “Pandemic Covid-19: The Opportunities and Challenges to Using ICT in Mathematics Learning,” *IJEBD Int. J. Entrep. Bus. Dev. eISSN 2597-4785 pISSN 2597-4750*, 2020.

[6] J. Naidoo, “Postgraduate mathematics education students’ experiences of using digital platforms for learning within the COVID-19 pandemic era,” *Pythagoras*, 2020, doi: 10.4102/PYTHAGORAS.V41I1.568.

[7] R. Cassibba, D. Ferrarello, M. F. Mammana, P. Musso, M. Pennisi, and E. Taranto, “Teaching mathematics at distance: A challenge for universities,” *Educ. Sci.*, 2021, doi: 10.3390/EDUCSCI11010001.

[8] Mailizar, A. Almanthari, S. Maulina, and S. Bruce, “Secondary school mathematics teachers’ views on e-learning implementation barriers during the COVID-19 pandemic: The case of Indonesia,” *Eurasia J. Math. Sci. Technol. Educ.*, 2020, doi: 10.29333/EJMSTE/8240.

[9] T. Tang, A. M. Abuhmaid, M. Olaimat, D. M. Oudat, M. Aldhaeebi, and E. Bamanger, “Efficiency of flipped classroom with online-based teaching under COVID-19,” *Interact. Learn. Environ.*, 2020, doi: 10.1080/10494820.2020.1817761.

[10] A. J. Berkova and R. Nemec, “Teaching theory of probability and statistics during the covid-19 emergency,” *Symmetry (Basel).*, 2020, doi: 10.3390/SYM12091577.

[11] M. L. George, “Effective Teaching and Examination Strategies for Undergraduate Learning During COVID-19 School Restrictions,” *J. Educ. Technol. Syst.*, 2020, doi: 10.1177/0047239520934017.

[12] W. F. Castro, L. R. Pino-Fan, J. G. Lugo-Armenta, J. A. Toro, and S. Retamal, “A Mathematics Education Research Agenda in Latin America Motivated by Coronavirus Pandemic,” *Eurasia J. Math. Sci. Technol. Educ.*, 2020, doi: 10.29333/ejmste/9277.

[13] L. H. Newman, “The App That Will Make Algebra Classes Seem Even More Pointless,” 2014. https://slate.com/technology/2014/10/photomath-apps-solves-problems-and-equations-and-shows-the-steps.html.

[14] F. Sayed, “Mathematics and mobile learning,” 2015.

[15] D. & Nguyen and D. Chen, “PHOTOMATH – A MOBILE APP FOR ALGEBRA TEACHING AND TUTORIALS,” 2016, pp. 264–266.

[16] J. Gonzalez, “The Teacher’s Guide to Tech,” *2020*. https://teachersguidetotech.com/.

[17] E. Wasserman and E. Berger, “MATH TEACHER’S VIEW ON INTEGRATING COMPUTERS IN THE CLASSROOM,” 2019, doi: 10.21125/edulearn.2019.2571.

[18] K. Saundarajan, S. Osman, J. A. Kumar, M. F. Daud, M. S. Abu, and M. R. Pairan, “Learning Algebra using Augmented Reality: A Preliminary Investigation on the Application of Photomath for Lower Secondary Education,” *Int. J. Emerg. Technol. Learn.*, 2020, doi: 10.3991/ijet.v15i16.10540.

[19] A. Z. Wali and M. E. Omaid, “The use of smartphones as an educational tool in the classroom: Lecturers’ perceptions,” *Int. J. Emerg. Technol. Learn.*, 2020, doi: 10.3991/ijet.v15i16.14179.

[20] I. Hamadneh and A. Al-Masaeed, “Math teachers’ attitudes towards photo math application in solving mathematical problem using mobile camera,” *Educ. Res. Rev.*, 2015.

[21] K. A. A. Gamage, E. K. de Silva, and N. Gunawardhana, “Online delivery and assessment during COVID-19: Safeguarding academic integrity,” *Educ. Sci.*, 2020, doi: 10.3390/educsci10110301.

[22] Z. R. Khan and S. Balasubramanian, “Students go click, flick and cheat... e-cheating, technologies and more,” *J. Acad. Bus. Ethics*, 2012.

[23] C. Webel and S. Otten, “Teaching in a World with PhotoMath,” *Math. Teach.*, 2015, doi: 10.5951/mathteacher.109.5.0368.

[24] N. Cox, “Using online tools for learning, not copying,” 2020.

[25] J. N. Lazarus, “SUPPORTING PROFESSIONAL LEARNING AND RESEARCH IN A COLLABORATIVE INQUIRY,” University of Ottawa, 2020.

[26] G. George, “On the Road to Modification and Redefinition,” 2017. https://blogs.svvsd.org/math/2017/11/14/on-the-road-to-modification-and-redefinition/.

[27] R. R. Puentedura, “SAMR : A contextualized introduction,” *Alberta Chart. Sch. Conf.*, 2013.

[28] A. Parker, “HOW TO WRITE SOLVER-RESISTANT PROBLEMS,” [Online]. Available: https://rederly.com/finals-conference.

[29] “MyOpenMath Forum on General Comments/Discussions.” https://www.myopenmath.com/forums/posts.php?cid=1&forum=37&thread=814348&page=1.

[30] “Introduction to Matlab for Engineers,” *Ind. Robot An Int. J.*, 1998, doi: 10.1108/ir.1998.04925dae.002.

[31] "Wikipedia." https://en.wikipedia.org/wiki/Mathematical_table.