

Learning Algebra Using Augmented Reality

A Preliminary Investigation on the Application of Photomath for Lower Secondary Education

<https://doi.org/10.3991/ijet.v15i16.10540>

Kartigeyan Saundarajan (✉), Sharifah Osman, Mohd Fadzil Daud,
Mohd Salleh Abu, Mohamad Rasidi Pairan
Universiti Teknologi Malaysia, Johor Bahru, Malaysia
kartikptse11@gmail.com

Jeya Amantha Kumar
Universiti Sains Malaysia, Pulau Pinang, Malaysia

Abstract—This study aims to determine the effect of Photomath mobile application on the achievement and attitude of learning algebraic equations for lower secondary school students in Malaysia. Photomath is a free mobile application, for both ios and android platforms, which uses computer vision and image understanding technology to scan math equations using the mobile camera to subsequently provide worked solutions. The application recognises equations of both printed and handwritten and provides step-by-step calculations and graphical solutions. In this study, data were collected from 33 lower secondary students through pre and post-test and questionnaire. Data from pre-test and post-test were used to investigate the performance of students after the application of Photomath, whereas the questionnaire was used to identify the attitude of students towards the application of Photomath in learning algebraic equations, regarding belief and readiness aspects. Different mean scores for pre-test and post-test were tested, and hypothesis testing using a t-test was used. Data from the questionnaire were analysed using descriptive statistics. This study has found that the application of Photomath significantly enhances the learning of algebraic equations among Form Two students. However, the participants' belief and readiness towards Photomath are still at a moderate level.

Keywords—Algebraic equation, Photomath, augmented reality, educational technology.

1 Introduction

TIMSS 2011 report analysis shows the performance of Malaysian students in mathematics education experienced a sharp decline between 1999 and 2000, 2011. According to the TIMSS report, countries that score below the average score of 475 indicate that the category of students of the country is only capable of using basic math knowledge and they are still unable to apply mathematical knowledge. This

indicates that our students are only understanding the basic concept but generally cannot apply knowledge (Ministry of Education, 2013). The TIMSS report 2007, states that the field of algebra has a score lower average (454) than field number (491) and geometry field (477). Therefore, research in the field of algebra and problem solving is appropriate as an initial step to ensure improvement in understanding the topic as well as what and how the strategy is going to be implemented by teachers when conveying the lesson to students.

In mathematics, algebra is a major component, with its uses extended to almost all other disciplines of mathematics such as arithmetic, geometry, statistics, and calculus. Algebraic thinking is essential to comprehend and interpret real-world problems mathematically to ultimately find the solution, which is often abstract (Ling, Osman, Daud, and Hussin, 2019; Nurhayati, Herman, & Suhendra, 2017). In Malaysia's 2013 Secondary School Mathematics Teaching and Learning Syllabus, algebra continues to be a foundation discipline. However, algebra has been deemed as difficult by the majority of students due to its abstract thinking nature (Ganesen, Osman, Abu, & Kumar, 2020; Susac, Bubic, Vrbanc, & Planinic, 2014).

The current world we are living in is deemed to be undergoing the fourth industrial revolution (4IR), where digitisation and automation have become governing factors in almost all major sectors of the world. Technology is an important part of the 21st century and we are currently using technology in every aspect of our lives (Abidin & Hunter, 2017). Application of augmented reality in mathematics education can help students with higher self-efficacy to have more involvement with the contents to be learned towards higher level conceptions (Cai, Liu, Yang, and Liang, 2019; Coimbra, Cardoso, and Mateus, 2015). In the wake of AR in mathematics education, an independent software company called Microblink has launched a mobile app called Photomath in 2014. In that context, this study was developed to investigate the effect of Photomath as a CVI tool in enhancing the learning of algebraic equations and to identify the secondary students' attitude and belief towards learning algebra with Photomath.

2 Literature Review

The alternative education system known as education 4.0 has become a staple element in the global education system (Xing & Marwala, 2017). The exponential growth of digital technology has created a need for a digital-centric education system to produce a future generation that can fulfill the requirements of 4IR. The trending technology in the current education scenario is the augmented reality (AR), a technology which fuses virtual materials into a real-time situation or augments the reality to facilitate teaching and learning. The cyber-physical platform created by AR technology allows the user to interact with the augmented surrounding and makes the user able to feel in real-time up to a certain degree, which deeply enhances the learning experience (Xing & Marwala, 2017). AR technology mainly utilizes text and object identification technology to blend them seamlessly into the subject of learning. Since its inception in the early 2010s, AR technology is gaining widespread acclaim and atten-

tion in the education sector due to its ability to actively engage students in teaching and learning (Saidin, Halim, & Yahaya, 2015).

2.1 The need to learn Algebra with Augmented Reality through photomath

A 21st-century learning environment should be of multi-disciplinary, multifaceted, and flexible to allow teaching and learning processes to occur most effectively and desirably for educators and students. Students of the 21st century are expected to perform independently, where the educators play the role of facilitators to assist the process to transform students to become creative and innovative knowledge seekers with a considerable mastery over technology. In 2012 Programme for International Student Assessment (PISA), students representing Malaysia only able to rank 52 out of 65 countries enroll which took part in the PISA. Furthermore, Malaysian students scored an average of 440 points in mathematics and 426 points in Science, below the Trends in International Mathematics and Science Studies (TIMSS) average scale.

However, Asian countries topped the list in the ranking of the Pisa 2012 results. Shanghai, Singapore, Hong Kong, Taiwan, and Korea were the top five economies in the latest results released. Vietnam which was ranked on the 17th gained attention as the only third world economy in the top 20 best-performing list. A difference of 38 points on the Pisa scale was equivalent to one year of schooling. A comparison of scores showed that students in Shanghai were performing as though they had four or more years of schooling than 15-year-olds in Malaysia. Malaysia was continuously ranked in the bottom third in PISA and TIMMS. Despite having the highest budget allocation for the Ministry of Education, Malaysian students still fail to perform when it comes to math and science. Thus, the current pedagogy of math and science comes under scrutiny and calls for an integration of digital technology in Malaysian teaching and learning to enhance the process.

A digital technology-driven math lesson can engage students more actively in a meaningful way, reducing the chance for rote learning to occur. AR and Computer Vision and Image Understanding (CVI), being the trending digital technology in education, given the potential of this technology to bridge the gap between reality and subject of learning (Iyad & Aslan, 2015). In this research, the application of a CVI app called the Photomath in enhancing the learning of algebraic equations among Form Two students was explored.

2.2 Malaysian students in algebra mastery

The ability to solve algebraic equations is elementary for all students who enroll in science, engineering, and social sciences. Many researchers are interested in investigating the difficulties faced by most students in learning algebraic equations. The major factor for students' difficulty in algebra is caused by the inability of the students on differentiating arithmetic and algebra, or the effort to draw similarities between both disciplines (Egodawatte, 2009); Egodawatte (2019) concludes that difficulties in teaching algebra cannot be solved without any creative solutions. New and creative ways to learn and teach mathematics are possible using AR technology; Teachers can

create more engaging math activities for the students using AR with ample time-saving (Figueiredo, 2014).

Computer vision is a process that produces, from images of the external world, a description that is useful to the viewer and not cluttered with irrelevant information (Marr, 1978). Computer vision is the scientific technology of machines that see. Computer vision is concerned with the theory and technology for building artificial systems that obtain information from images or multi-dimensional data. There is an increasing interest in the area of Learning in Computer Vision and Image Understanding (CVI), both from researchers inside the learning network and from researchers involved with the computer imaginative and prescient world. The subject is characterised by a shift away from the classical, simple model-primarily based, computer vision techniques, towards facts-driven mastering paradigms for fixing actual-world vision troubles. Photomath, being able to integrate visual math equations into image understanding algorithms and subsequently solving it, can become the game-changer in the field of algebra learning (Iyad & Aslan, 2015).

Despite concerns over using Photomath to cheat homework by students, Photomath application has given rise to new dimensions in teaching algebra. Students should be learning more than what Photomath could deliver as a solution (Webel & Otten, 2015). Figure 1 shows an example of using Photomath in solving an algebraic equation. This app uses image capturing technology to scan math equations using the mobile's camera and provides a step-by-step solution for any math equation, ranging from basic arithmetic to advanced calculus. By harnessing state-of-the-art text recognition and image understanding, both printed and handwritten, Photomath able to provide solutions in both calculations and graphical methods in a matter of seconds, with an option for feedback from the user to the developer for continuous improvement of the app. Within mathematics education, technology is perceived as a valuable tool, the affordances of which allow mathematics learning to be reshaped and practised in distinctive ways (Abidin & Hunter, 2017; Torressibille, Cloquellballester, & Darton, 2009)

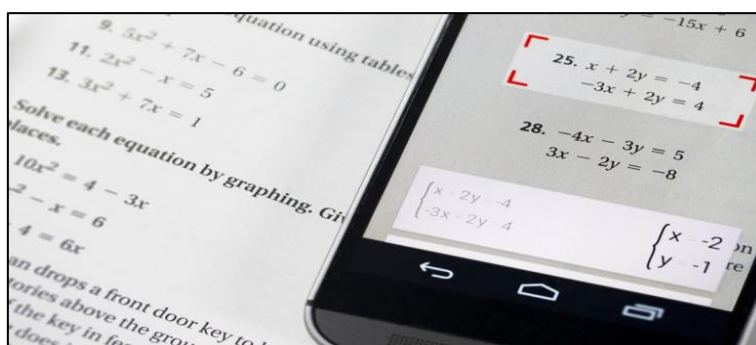


Fig. 1. Using Photomath for solving an algebraic equation

2.3 Belief and readiness

It becomes even more important to consider students' attitudes in developing countries as a key component that must be taken into account to ensure a smooth process of learning mathematics with technology. They demonstrated that holding a high level of confidence in using technology appeared to influence students in having a very positive attitude to learning mathematics with technology (Abidin & Hunter, 2017).

3 Method

This pre-experimental study was carried out to investigate the effectiveness of the application of Photomath in enhancing the learning of algebraic equations among Form Two students aged 14 years old. A pre-test consisted of 4 linear equation questions were administered by the researchers to the participants. Then, the participants were taught by the researchers on the application of Photomath in learning algebraic equations by using a treatment task, consisting of 4 linear equation questions of a similar level of difficulty with the pre-test. The participants used their mobile phones with the Photomath app pre-downloaded before the pre-test session. During the treatment task session, the participants were given a step by step briefing on how to use Photomath to solve and learn algebraic equations on their own.

After a window period of 2 weeks, intended for the participants to assimilate Photomath into their learning, students answered the post-test consisted of 4 linear equations of a similar level of difficulty with the pre-test. Subsequently, a questionnaire on belief and readiness of participants towards the application of Photomath was administered using a Likert scale. The 5 levels Likert scale was used with the range of 1 until 5 for showing strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree. In this study, the researchers used the Cronbach Alpha to check for the reliability of the instrument. The questionnaire shows the value of Cronbach Alpha which exceeds 0.7. Therefore, the instrument is acceptable to be used in this research.

The test papers were evaluated by the researchers and the marks were categorized into grades according to the current Ministry of Education's (MOE) standard. The descriptive analysis was used to elaborate on the mean and standard deviation of the scores as well as the demography of the participants. A one-sample t-test was calculated based on the gain obtained from the difference scores between pre-test and post-test.

4 Results and Discussion

Figure 2 illustrates the mean scores of pre-test and post-test for Form-Two students before and after the application of Photomath application respectively. The pre-test score was based on conventional learning of algebraic equations and the post-test score was after students receiving the treatment session on the usage of Photomath application in learning algebraic equations. The result showed a significant increase in the score of students on the post-test which is after the use of Photomath application.

This finding indicates that the Photomath application was effective for learning the algebraic equations among Form Two students.

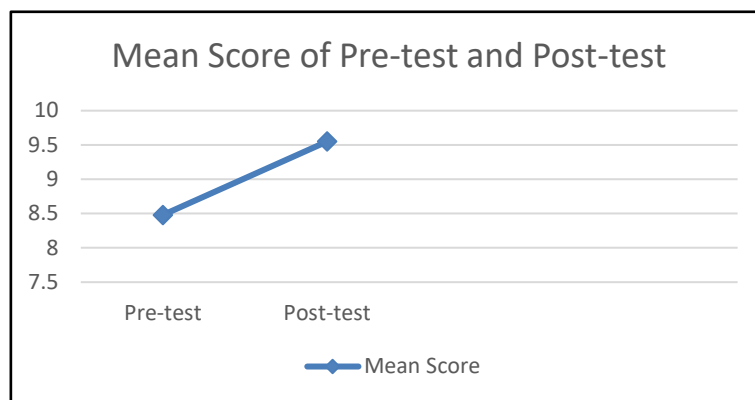


Fig. 2. Mean score of pre-test and post-test

Table 1 shows a t-test that performed between pre-test and post-test to investigate the significant level of achievement of Form Two students in school. The result showed that there was a significant difference between pre-test and post-test as $p < 0.05$. The mean score of the pre-test was recorded as 8.48 with a standard deviation of 5.338 and the mean score of the post-test was recorded as 9.55 with a standard deviation of 4.214. The hypothesis tested for this study was there is no statistically significant difference in test scores between pre-test and post-test in learning algebraic equations using Photomath. Statistically, the p-value was 0.000 which less than 0.05. This study showed that there was a significant difference in students' achievement between pre-test and post-test and thus this hypothesis is rejected.

Table 1. t-test between Pre-test and Post-test

Category	N	Mean	Std. Deviation	Std. Mean	t	df	Sig.(2-tailed)	Mean Difference
Pre	33	8.48	5.338	0.929	9.131	32	0.000	8.485
Post	33	9.55	4.214	0.734	13.013	32	0.000	9.545

Table 2 shows that 16 (48.5%) students agreed with the statement that Photomath application is an interesting method in learning algebraic equations. 13 (39.4%) students agreed that Photomath helps them to do independent learning. For the statement, "Photomath helps to understand and solve algebraic equations easily", 14 (42.4%) students neither agreed nor disagreed with it. Similarly, 17 (51.5%) students neither agreed nor disagreed with the statement that Photomath encourages 21st-century learning and lastly, 23 (69.7%) students agreed that Photomath application must be included in classroom learning.

Table 2. Belief Frequency Analysis

Belief	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
Photomath application is an interesting method to learn an algebraic equation.	1 (3.0%)	3 (9.1%)	12 (36.4%)	16 (48.5%)	1 (3.0%)
Photomath helps me to do independent learning.	4 (12.1%)	3 (9.1%)	11 (33.3%)	13 (39.4%)	2 (6.1%)
Photomath helps me to understand and solve algebraic equations easily.	1 (3.0%)	6 (18.2%)	9 (27.3%)	14 (42.4%)	3 (9.1%)
Photomath encourages 21 st -century learning.	2 (6.1%)	1 (3.0%)	17 (51.5%)	10 (30.3%)	3 (9.1%)
Photomath applications must be included in classroom teaching.	0 (0%)	0 (0%)	8 (24.2%)	2 (6.1%)	23 (69.7%)

Table 3 shows that 12 (36.4%) students strongly disagreed with statements that they have already known and have heard about Photomath application before this research is being carried out. 20 (60.6%) students neither agreed nor disagreed with the statement that they will use Photomath application to learn upcoming math topics before classroom lessons. Sharing knowledge on Photomath with other friends resulted in 11 (33.3%) students that agreed with that statement. 14 (42.4%) students strongly agreed that they clearly understand how to use Photomath in learning algebraic equations and similarly, 14 (42.4%) students agreed with the statement that they will use Photomath to help them with mathematics homework that involves equations.

Table 3. Readiness Frequency Analysis

Readiness	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
I have already known and have heard about the Photomath app before this research.	12 (36.4%)	7 (21.2%)	6 (18.2%)	6 (18.2%)	2 (6.1%)
I like to use Photomath app to learn upcoming math topics before classroom lessons.	6 (18.2%)	3 (9.1%)	20 (60.6%)	3 (9.1%)	1 (3.0%)
I will share my knowledge of Photomath with my family and friends.	3 (9.1%)	6 (18.2%)	7 (21.2%)	11 (33.3%)	6 (18.2%)
I clearly understand how to use Photomath in learning algebraic equations.	0 (0%)	3 (9.1%)	7 (21.2%)	9 (27.3%)	14 (42.4%)
I will use Photomath to help me with my math homework involving equations.	3 (9.1%)	2 (6.1%)	7 (21.2%)	14 (42.4%)	7 (21.2%)

Table 4 shows that students' belief towards Photomath application in solving algebraic equations in mathematics was still at a moderate level with a mean score of 3.55 and a standard deviation of 0.94. It might be due to Photomath application which was

still new to them and only launched recently. This assumption goes along with the students' readiness towards Photomath application in solving algebraic equations in mathematics which were also still at the moderate level with a mean score of 3.21 and a standard deviation of 1.15. The possible reason might be due to the unreadiness and resistance of the students to change their conventional methods of study to apply the Photomath application. Nevertheless, it can be concluded that students on average have more positive beliefs than average and feel more ready than average.

Table 4. Descriptive Analysis of Belief and Readiness Variables

Variables	N	Scale	Mean	Standard Deviation	Level
Belief	33	1-5	3.55	0.94	Moderate
Readiness	33	1-5	3.21	1.15	Moderate
TOTAL	33	1-5	3.38	1.05	Moderate

The results indicate that there was a significant increase in post-test scores after the implementation of Photomath. It on that the integration of Information, Communication, and Technology (ICT) helps to improve students' achievement of learning algebraic equations. This finding is in line with the research findings by Ghavifekr & Rosdy (2015) that teachers' well-equipped preparation with ICT tools and facilities is one of the principal factors in the success of technology-based teaching and learning (Ghavifekr & Rosdy, 2015). Moreover, according to Archer et al. (2014), to train and support teachers on how to use technology in their classroom instruction are important as a way to contribute to successful outcomes.

This study also showed that the level of belief and readiness of Form Two students towards Photomath application was still at a moderate level. Nevertheless, the students agreed that Photomath application works as an interesting method for them to learn algebraic equations. Most of them were not aware or heard about Photomath before this and they were not ready to use Photomath for the upcoming math topics before classroom lessons. However, they agreed to share their knowledge on Photomath with their family and friends and moderately understand how to use Photomath in learning algebraic equations. They also agreed that Photomath application helps them to do independent learning and helps them to solve algebraic equations easily. These findings indicate 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.

5 Conclusion

The findings of this study showed that the application of Photomath has a positive impact on enhancing the learning of algebraic equations among Form Two students as there was a statistically significant difference between the pre-test and post-test mean scores, which was increased from 8.5 to 9.5. In terms of belief and readiness, the majority of the participants are moderately receptive to the application of Photomath in learning. This might be due to the fact of lacking prior exposure of Malaysian stu-

dents towards digital technology integration in education. This research provided an outlook on a comparison between the conventional learning and digital technology-aided education through Photomath application in terms of its implications on learners' experience and motivation through the usage of pre-test, post-test, surveys, and students' remarks. Regarding practical implications, the research robustly emphasised the integration of digital technology into current mathematics teaching and learning, which can lead to significant changes in terms of perception and practice of the general public towards new-age curricula.

6 Acknowledgement

This work was supported by the Contract Research Grant (R.J130000.7651.4C221).

7 References

- [1] Abidin, Z., & Hunter, R. (2017). Student Engagement with Technology Use in Mathematics Education: An Indonesian Secondary School Context Student Engagement with Technology Use in Mathematics Education: An Indonesian Secondary School Context. In Twenty-First Pacific Asia Conference on Information Systems. <https://doi.org/10.4324/9781351189392-7>
- [2] Archer, K., Savage, R., Sanghera-Sidhu, S., Wood, E., Gottardo, A., & Chen, V. (2014). Examining the effectiveness of technology use in classrooms: A tertiary meta-analysis. *Computers & Education*, 78, 140-149. <https://doi.org/10.1016/j.compedu.2014.06.001>
- [3] Biggs, J., & Biggs, J. (1999). Assessing for learning quality: II. Practice. *Teaching for Quality Learning at University*, 165–203. <https://doi.org/10.1097/00005176-200304000-00028>.
- [4] Cai, S., Liu, E., Yang, Y., & Liang, J. (2019). Tablet-based AR technology: Impacts on students' conceptions and approaches to learning mathematics according to their self-efficacy. *British Journal of Educational Technology*, 50(1), 248–263. <https://doi:10.1111/bjet.12718>.
- [5] Coimbra, M. T., Cardoso, T., & Mateus, A. (2015). Augmented Reality: anReality: for Higher Education Students in Math's learning? *Procedia - Procedia Computer Science*, 67, 332–339. <https://doi:10.1016/j.procs.2015.09.277>.
- [6] Egodawatte, G. (2009). Is algebra really difficult for all students? *Acta Di-dactica Napocensia*, 2(4), 101–106.
- [7] Figueiredo, M. (2014). Teaching Mathematics with Augmented Reality. Framework for 21st Century Learning - P21. (n.d.). Retrieved March 23, 2018, from <http://www.p21.org/our-work/p21-framework>.
- [8] Ganesen, P., Osman, S., Abu, M. S., & Kumar, J. A. (2020). The Relationship Between Learning Styles and Achievement of Solving Algebraic Problems Among Lower Secondary School Students. *International Journal of Advanced Science and Technology*, 29(9S), 2563–2574.

- [9] Ghavifekr, S., & Rosdy, W. A. W. (2015). Teaching and Learning with Technology: Effectiveness of ICT Integration in Schools. *International Journal of Research in Education and Science*, 1(2), 175-191. <https://doi.org/10.21890/ijres.23596>
- [10] Iyad, M. H., & Aslan, A. M. (2015). Math teachers attitudes towards photo math application in solving mathematical problem using mobile camera. *Educational Research and Reviews*, 10(14), 1930–1936. <https://doi.org/10.5897/ERR2015.2181>.
- [11] Kementerian Pendidikan Malaysia. (2017). *Jurnal Penyelidikan Pendidikan (Educational Research Malaysia)* Retrieved from <https://www.moe.gov.my/images/KPM/BPPDP/Media/Penerbitan/Jurnal2017.pdf>.
- [12] Ling, C. Y., Osman, S., Daud, M. F., & Hussin, W. N. W. (2019). Application of Vee Diagram as a Problem-Solving Strategy in Developing Students' Conceptual and Procedural Knowledge. *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, 8(10), 2796–2800. <https://doi.org/10.35940/ijitee.j9591.0881019>.
- [13] Marr, D. (1978). Representing visual information. *Computer vision systems*, 61-80.
- [14] Ministry of Education Malaysia. (2013). *Malaysia Education Blueprint 2013-2025 (Pre-school to Post-Secondary Education)*. Ministry of Education Malaysia, 292. <https://doi.org/10.5923/j.ijis.20120206.05>.
- [15] Nurhayati, D. M., Herman, T., & Suhendra, S. (2017). Analysis of Secondary School Students' Algebraic Thinking and Math-Talk Learning Community to Help Students Learn. *Journal of Physics: Conference Series*, 895(1). <https://doi.org/10.1088/1742-6596/895/1/012054>.
- [16] Saidin, N. F., Halim, N. D. A., & Yahaya, N. (2015). A review of research on augmented reality in education: Advantages and applications. *International Education Studies*, 8(13), 1–8. <https://doi.org/10.5539/ies.v8n13p1>.
- [17] Susac, A., Bubic, A., Vrbanc, A., & Planinic, M. (2014). Development of abstract mathematical reasoning: the case of algebra. *Frontiers in Human Neuroscience*, 8(September), 1–10. <https://doi.org/10.3389/fnhum.2014.00679>.
- [18] Torressibille, A., Cloquellballester, V., & Darton, R. (2009). Development and validation of a multicriteria indicator for the assessment of objective aesthetic impact of wind farms. *Renewable and Sustainable Energy Reviews*, 13(1), 40–66. <https://doi.org/10.1016/j.rser.2007.05.002>.
- [19] Webel, C., & Otten, S. (2015). Teaching in a world with PhotoMath. *Mathematics Teacher*, 109(5), 368–373. <https://doi.org/10.5951/mathteacher.109.5.0368>
- [20] Xing, B. B., & Marwala, T. (2017). Implications of the Fourth Industrial Age for Higher Education. *The Thinker*, 73, 10–15.

8 Authors

Kartigeyan Saundarajan is a Postgraduate in Education, School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia. shahrin@utm.my.

Sharifah Osman is a Senior Lecturer in Education, School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia.

Jeya Amantha Kumar is a Senior Lecturer in [Centre for Instructional Technology and Multimedia](#), Universiti Teknologi Malaysia.

Mohd Fadzil Daud is a Senior Lecturer in Mechanical Engineering, School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia.

Mohd Salleh Abu is a Professor of Mathematics Education, School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia.

Mohamad Rasidi Pairan is a Senior Lecturer in Education, School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia.

Article submitted 2019-03-22. Resubmitted 2020-05-20. Final acceptance 2020-05-23. Final version published as submitted by the authors.