TEACHING EXPONENTIAL FUNCTION PROPERTIES: PRACTICAL AND EXPERIENTIAL ACTIVITIES ON SMARTPHONE

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Abstract

This study mainly forms knowledge about Properties of Exponential Functions content for 11th-grade students through practical and experiential activities based on David Kolb's Experiential Learning Theory using smartphones. The research focuses on the perspectives of teaching these properties through practical and experiential activities in Mathematics. The content of the learning situation revolves around having students practice on smartphones through GeoGebra embedded on the Google Sites website and answer a set of questions, thereby forming the target knowledge for students. The study emphasizes the effectiveness of teaching Math through practical and experiential activities in the information technology environment, specifically mobile phones. This approach is consistent with modern educational trends, aiming to make mathematics more applicable, attractive, and effective.

Keywords: *Exponential functions, mobile learning, practical and experiential activities, smartphone.*

DẠY HỌC TÍNH CHẤT HÀM SỐ MŨ: HOẠT ĐỘNG THỰC HÀNH VÀ TRẢI NGHIỆM TRÊN ĐIỆN THOẠI THÔNG MINH

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Tóm tắt

Bài nghiên cứu này chủ yếu hình thành kiến thức nội dung các tính chất hàm số mũ cho học sinh lớp 11 thông qua hoạt động thực hành và trải nghiệm dựa trên Lý thuyết Học tập trải nghiệm của David Kolb trên điện thoại thông minh. Nghiên cứu tập trung vào việc dạy học tính chất hàm số mũ thông qua hoạt động thực hành và trải nghiệm Toán. Nội dung tình huống học tập xoay quanh việc cho học sinh thực hành trên điện thoại thông minh thông qua GeoGebra được nhúng trong website Google Sites và trả lời bộ câu hỏi, từ đó hình thành kiến thức về tính chất của hàm số mũ cho học sinh. Nghiên cứu nhấn mạnh tính hiệu quả của việc dạy học Toán thông qua thực hành và trải nghiệm toán trong môi trường công nghệ thông tin, đặc biệt là điện thoại di động. Cách tiếp cận này phù hợp với xu hướng giáo dục hiện đại, nhằm làm cho toán học trở nên dễ áp dụng, hấp dẫn và hiệu quả hơn.

Từ khoá: *Điện thoại thông minh, hàm số mũ, hoạt động thực hành và trải nghiệm, học tập di động.*

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1. Introduction

1.1. Teaching Exponential Functions

The exponential function, with the mathematical formula $f(x)=a^x$ (where a is a positive constant different from 1), is one of the most widely applied mathematical tools in various fields. This demonstrates the importance and necessity of studying exponential functions for students. In the 2018 General Education Program, there is an increased inclusion of financial problems in general and problems involving exponential functions specifically. In Vietnam, many students lack financial knowledge, and parents are often reluctant to share money management skills with their children (Nguyen & Lam, 2023). Therefore, it is evident that helping students grasp the knowledge of exponential functions and their properties is essential.

According to Nguyen and Lam (2023), the integration of financial education in teaching exponential functions for grade 12th students not only helps students improve their ability to apply mathematical knowledge but also popularizes the new knowledge about using credit cards in life, helping them make appropriate financial choices in the future.

A study by Dias et al. (2021) introduced a model that can teach exponential functions through didactic situations. Exponential function point outs that the teaching process mostly occurs in a classic habitual way, that is, it essentially comprises object definition, examples and resolution of activities, most likely direct influence from the textbook adopted as the only methodological support reference. Such facts point to the need to present other didactic resources for the teaching of mathematics beyond the textbook, in our case, a didactic sequence.

Makgakga and Sepeng (2013) carried out a study of the advantages of an exponential and logarithmic functioning transformation approach in 12-year mathematical schools. The study followed a pre-test - intervention - post-test design with qualitative data informing quantitative information. Data collection strategies included a test (on exponential and logarithmic functions) given to learners before and after the intervention. The intervention strategy was carried out to enhance conceptual understanding by teaching exponential functions through the transformation approach.

Additionally, Nunes et al. (2017) analyzed mathematical content related to the teaching and learning of exponential functions in a freshman group of students registered in the first semester of the Science Bachelor and Technology. As a contextualization tool strongly mentioned in the literature, the modeling approach was used as an educational tool for contextualizing exponential functions in the teaching-learning process. Similarly, Sawalha (2018) researched the effectiveness of solving exponential problems to impact students' achievements and attitudes.

Regarding the teaching of Exponential Functions in grade 11 in Vietnam, the 2018 General Education Program in Mathematics outlines the objectives: "Identify the graphs of exponential and logarithmic functions" and "Explain the properties of exponential and logarithmic functions through their graphs." (Ministry of Education and Training, 2018b, p.95). Additionally, the 2018 Program emphasizes practical activities using mathematical software: "Practice using software to plot graphs of power functions, exponential functions, and logarithmic functions, and explore their characteristics." (Ministry of Education and Training, 2018b, p.96). Based on these requirements, it is clear that integrating information technology, specifically using mathematical software on mobile phones for teaching Exponential Functions through experiential activities, aligns well with the new program.

1.2. Practical and Experiential Activities

Experiential activities emphasize practical activities that foster student autonomy, fundamentally being collective activities based on individual autonomy, with educational efforts aimed at developing creativity and the unique personality of each individual within the group (Vu et al., 2023). Experiential activities are mandatory educational activities, where students mobilize comprehensive knowledge and skills from various educational fields to undergo practical experiences under the guidance and organization of teachers, thereby forming core qualities, general capabilities, and some specific skills, enhancing awareness of the objective world (Dang Thi, 2020; Nguyen et al., 2022).

From another perspective, practical and experiential activities are not only applied in Vietnam. Globally, these activities are referred to

as "experiential learning." Experiential learning is a comprehensive educational philosophy based on the view that life experiences, education, and the activities of each individual play a central role in the learning process and in understanding new knowledge (Fry et al., 2009; Kolb & Kolb, 2009).

Veillon (2019) compared the effectiveness of knowledge acquisition among students in two different learning environments: traditional teaching and experiential learning. From this, it shows that experiential learning is just as effective as traditional Mathematics instruction in the mathematics classroom, students in classrooms where experiential learning is used are more engaged with the concept than students in a traditional mathematics instruction classroom, and providing professional development for high school mathematics teachers may generate positive results in the classroom.

Venkatraman et al. (2019) show that experiential learning positively impacts students' mathematical creativity. The study of Chesimet et al. (2016) found that the experiential learning method is more effective than traditional teaching and learning methods in enhancing students' mathematical creativity. As a result, students who engage in experiential learning can better express their creativity in mathematics and develop their critical thinking skills.

In terms of actual teaching practices in Vietnam, Vu et al. (2023) noted that experiential learning aligns with the objectives of the 2018 General Education Program. In the new 2018 Program, experiential activities are organized into three categories: general educational activities, subject-related educational activities, and experiential activities integrated into teaching methods within lessons (Tang et al., 2021). Experiential activities in teaching mathematics at the high school level involve students directly exploring and discovering mathematical knowledge based on their own prior experiences, gradually transforming these experiences under appropriate guidance from teachers to achieve the learning objectives (Vu et al., 2023). Experiential learning in mathematics education has become a major trend in current education (Nguyen & Ho, 2023). According to the 2018 General Education Program, teaching methods emphasize student-centered learning, where students actively acquire knowledge to develop competencies and personal qualities. Additionally, active teaching methods focus on organizing learning activities based on the principle of "learning by doing." This shows that incorporating experiential activities into mathematics teaching fully meets the requirements of the 2018 Program.

1.3. Teaching on Smartphones

Along with the robust development of information technology, the education sector has also modernized through programs that incorporate Information Technology into teaching. Information technology in general, and smartphones in particular, enable teachers to implement modern teaching methods such as virtual classrooms, group learning online, and provide immediate feedback to students through online educational platforms. This not only enhances interaction between teachers and students but also encourages participation and interaction among students, thereby improving learning effectiveness.

In fact, many teachers have adopted smartphone-based teaching, and numerous researchers have demonstrated the benefits of using information technology in education or simply proposed educational activities on smartphones. Rapid scientific and technological advances in the globalization era encourage students to acquire various skills, knowledge, and attitudes (Fitriani et al., 2020). That way, students have the skills to use technology in the learning process so that their thinking and learning skills can be improved in the teaching process (Umayah & Riwanto, 2020).

Sumandya and Widana (2022) produced vocational-based math teaching materials using smartphones that meet valid, practical, and effective prerequisites.

Rifa'i and Sugiman (2018) unravel student perception of mathematics mobile blended learning using smartphones. Students are helped by the material in the form of explanations, animations, pictures, and diagrams presented in the web aide and can be accessed from anywhere and anytime via smartphones. Students indicate that the mobile assessment feature is effective to help them learn mathematics. In general, students have a positive perspective toward mobile blended learning so it can be said that mobile blended learning is quite qualified.

In Vietnam, the Ministry of Education and Training also recommends that schools use information and communication technologies to enhance teaching and learning activities (Trinh et al., 2019). Circular 32/2020/TT-BGDĐT provided guidance stating that mobile phones mustn't be used during class time unless for educational purposes and with the teacher's permission (Ministry of Education and Training, 2018a). It has created opportunities for students to use smartphones for learning. Furthermore, the 2018 General Education Program emphasized the role of modern education in enhancing information and communication technologies skills and incorporating educational research advancements from competency-based models in advanced education systems worldwide (Nguyen & Quach, 2023). Additionally, according to Le and Tran (2021), after the COVID-19 pandemic, when educational institutions were forced to close, home-based learning and distance education became essential. This situation encouraged teachers to gradually accept smartphones as a tool for teaching. Nguyen and Quach (2023) also concluded that using information and communication technologies in education empowers students to take a more active role, taking them at the center of the learning process. Therefore, applying information and communication technologies in teaching makes lessons more engaging and meaningful.

Through the analysis of the exponential function teaching program, the trend of education through practical activities and experiences, along with the benefits of smartphones, it is essential to develop experiential activities on mobile phones to help students thoroughly understand the knowledge of exponential functions. Therefore, this study aimed to elucidate the following question: To what extent do practical and experiential activities on smartphones enhance student's understanding of Properties of Exponential Functions in 11th grades?

2. Method

2.1. Participants

The teaching situation was implemented with 62 11th-grade students in Ho Chi Minh City, Vietnam. The students were taught about the definition of exponential functions. All students have learned this content and are prepared to learn the properties of exponential functions.

2.2. Learning Activities

This situation took place after students had learned the definition of exponential functions and before studying the properties of exponential functions. Students practiced on smartphones by accessing the website: https://sites.google.com/view/toan11hsm/ including a GeoGebra file embedded in Google Sites and a form (Google Forms) attached below.

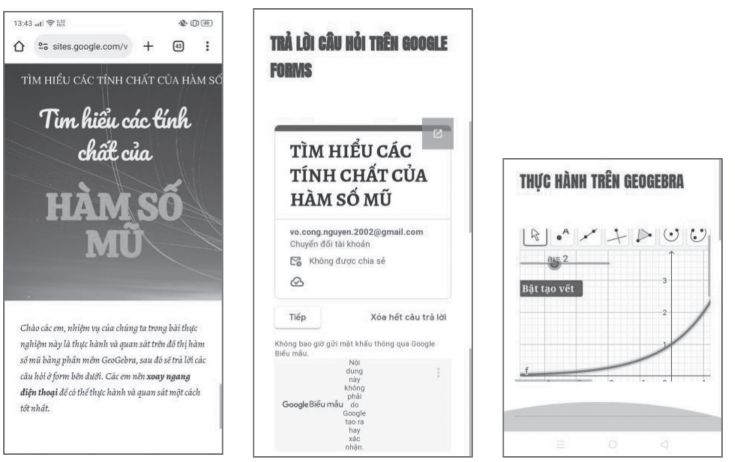

Figure 1. Student working website interface.

Work content: Students practiced and observed on GeoGebra embedded on the website to answer corresponding questions in Forms. The questions were divided into five parts, students practiced on GeoGebra and answered the questions. All responses of students were saved to an Excel spreadsheet.

Table 1. Questions and expected answers

No.	Questions	Expected answer
PART 1: STUDY ON THE DOMAIN OF EXPONENTIAL FUNCTIONS		
1	Change the base a by dragging the red point on the slider. After observing the graph of the function, state: For which values of a does the screen display the graph of the function?	a>0,a≠1
2	Change the base a by dragging the red point on the slider. After observing the graph of the function, state: In which interval does the abscissa of the points on the graph of the function change?	(-∞;+∞) or ℝ
3*	State the domain of the exponential function	(-∞;+∞) or ℝ
PART 2: STUDY ON THE RANGE OF EXPONENTIAL FUNCTIONS		
4	*Change the base a by dragging the red point on the slider. After observing the graph of the function, state: In which interval does the ordinate of the points on the graph of the function change?*	(0;+∞)
5*	State the range of the exponential function	(0;+∞)
PART 3: STUDYING THE CONTINUITY OF EXPONENTIAL FUNCTIONS		
6	*Change the base a by dragging the red point on the slider. After observing the graph of the function, state: Is the graph of the function a solid or dashed line?*	A solid line
7*	Provide comments on the continuity of the exponential function.	The exponential function is continuous over ℝ.
PART 4: STUDY ON THE VARIATION OF EXPONENTIAL FUNCTIONS		
8	*Change the base a by dragging the red point on the slider. After observing the graph of the function, state: Is the graph of the exponential function going in one direction (up/down) or winding (sometimes up, sometimes down)?*	The graph of the exponential function moves in one direction.
9	*Change the base a by dragging the red point on the slider. After observing the graph of the function, state: For which values of a does the graph of the function trend upward?*	(1;+∞) or a>1.
10	*Change the base a by dragging the red point on the slider. After observing the graph of the function, state: For which values of a does the graph of the function trend downward?*	(0;1) or 0<a<1
11*	Provide comments on the monotonicity (increasing) and non-monotonicity (decreasing) of the function.	The function is monotonically increasing over ℝ when a > 1, and monotonically decreasing over ℝ when 0 < a < 1.
PART 5: STUDY ON THE POSITION AND INTERSECTIONS OF THE GRAPH OF EXPONENTIAL FUNCTIONS WITH COORDINATE AXES		
12*	*Press the "Enable tracing" button and change the base a by dragging the red point on the slider. Observe the graph of the function and state: Where is the graph of the function located relative to the x-axis?*	Over
13*	*Press the "Enable tracing" button and change the base a by dragging the red point on the slider. Observe the graph of the function and state: What are the coordinates of the intersections (if any) of the graph of the exponential function with the x-axis a*	There are no intersections with the horizontal axis, and the coordinates of the intersection with the vertical axis are (0; 1).

- Questions marked with * (for example 3*, 5*, ...) are knowledge key questions, students are considered to have knowledge if they can answer these questions.

- The remaining questions are practice questions on GeoGebra that suggest answers for students.

2.3. Collecting and Analyzing Data

This study is interested in the results of forming knowledge about the properties of exponential functions through experiential activities from students' answers through the form. These responses were recorded in an Excel file.

Filter data: In the received Excel file, filter out noisy answers (meaningless answers and answers submitted outside of class time).

Data analysis: From students' answers, statistically calculated the percentage of students answering correctly, the types of student errors, and predicted the reasons why students were wrong (if the rate of incorrect answers follows this type of response). Note that we only analyzed the students' answers based on our expected answers, which means that when we say the student answered "wrong," we mean the answer does not match our expectations.

Students' work results are analyzed qualitatively through student answer data.

3. Findings

3.1. Study on the Domain of Exponential Functions

In questions 1, 2 and 3, respectively, there are 5, 37 and 58 students answered correctly as expected.

Question 1 was mostly answered incorrectly by the students, which may have been due to the question not being clear about excluding the constant function graph y=1. From the three questions in part 1 regarding the domain, most students correctly answered the domain of the exponential function. However, among the 25 students who answered question 2 incorrectly, most responses were "unchanged." We observed that the students did not understand the questions and were confusing changes in the x-coordinates of points on the graph with changes in the domain of the function.

3.2. Study on the Range of Exponential Functions

Forty-seven students answered question 4 correctly, and 58 answered question 5 correctly.

In question 4, the most common type of error among students was answering about the change in the y-coordinates relative to the x-coordinates of points on the graph of the function, indicating that the students did not understand the content of the question. The second type of error, like that seen in part 1, suggests that students could not distinguish between the change in the y-coordinates of the points on the graph and the change in the range of the function. The manifestation of this type of error was the response "unchanged".

3.3. Study on the Continuity of Exponential Functions

In questions 6 and 7, respectively, 61 and 55 students answered correctly as expected.

In question 6, which was a multiple-choice question, almost all students were able to observe and answer correctly, with only one student answering incorrectly. The accuracy rate dropped for question 7, where many students misread the prompt, leading to answers that were irrelevant to the continuity of the exponential function.

3.4. Study on the Variation of Exponential Functions

This section has four questions, including questions 8, 9, 10, and 11. In order, 41, 57, 54, and 41 students answered correctly.

The questions in this section differ from those in other sections because the answers are similar across multiple questions. The results show that more than half of the students were able to observe and answer this set of questions correctly. Due to the unique nature of these questions compared to other sections, if students answered a previous question incorrectly, it could lead to incorrect responses to subsequent questions. Evidence of this pattern is seen in that most students who answered question 10 incorrectly also got question 11 wrong. The most common type of error in this section occurred in question 10, where students forgot the initial condition that $a>0$. The second most frequent error was found in the answers to question 11, where students confused the interval of increase of the function with the range of a for the function to be increasing, and similarly with the interval of decrease of the function.

3.5. Study on the Location and Intersections of the Exponential Functions Graph with the Coordinate Axis

In question 12, 61 students answered correctly, and the number of students answering correctly in question 13 was 45.

Question 12 is like question 6 as it is a multiple-choice type, making it relatively easy for the students. This is evidenced by 61 out of 62 students answering this question correctly. For question 13, 45 out of 62 students answered correctly. The majority of those who answered incorrectly did so primarily due to misunderstandings in reading the prompt, as these students responded with content that was unrelated to the question.

4. Discussion

From the results of the students through 5 parts of the question, the findings show that students can completely grasp the knowledge of Exponential Functions through practical and experiential activities on smartphone, as evidenced by the fact that the majority of students (over 65%) participating in the experiment answered correctly as expected by the authors. That means that over 65% of students participating in the experiment have knowledge of Exponential Functions. It can be seen that learning through experiential activities, or "learning by doing", shows more innovation and progress than traditional teaching methods when students can actively grasp knowledge and are the center of teaching and learning activities.

Based on Kolb's Experiential Learning Theory, along with an analysis of the 2018 General Education Program in Mathematics and the benefits of learning with mobile phones, we build situations for teaching the content of Exponential functions for 11th-grade students through practical and experiential activities on mobile phones, thereby forming knowledge about the properties of exponential functions for students.

Under that teaching approach, specifically practicing on GeoGebra (embedded in Google Sites), students can observe, analyze, and form the properties of exponential functions (Tuda & Rexhepi, 2023). Besides, it allows students to operate and study on mobile phones and also generates positive feedback from students, thereby helping students learn more effectively (Fabian et al., 2018).

We see similarities between this study and the above in applying information technology to teaching mathematics, specifically using mobile phones and GeoGebra (embedded with Google Forms). Many studies also show the effectiveness of teaching using experiential activities combined with information technology. This research article also continues the teaching ideology of helping students proactively grasp knowledge and proactively master lesson content through activities that students directly perform. This research is especially suitable for the Vietnamese context and is consistent with the goals of the 2018 General Education Program.

5. Conclusion

Exponential functions play a crucial role in various practical and technical fields such as finance, biology, physics, and technology. Key areas include growth models, interest calculations, and radioactive decay. Clearly, exponential functions are widely applied across many industries and fields. Therefore, understanding exponential functions is an essential requirement in high school mathematics education. To achieve this, an active teaching method that aligns with current trends is teaching exponential functions through experiential activities combined with the application of information technology in teaching. Hence, this research holds practical significance for teaching mathematics in high schools.

This research can be easily applied to classroom teaching because it meets the requirements of the 2018 General Education Program in Mathematics. The above situation helps students actively absorb knowledge, and working on Mobile phones will easily attract students, making the classroom atmosphere more dynamic. However, the situation only really goes smoothly when all students in the class are equipped with smartphones and stable internet connections. In addition, some low-configuration phones can produce "error" images, leading to inaccurate student observation practices.

In summary, the research has established knowledge about exponential properties for 11th-grade students through practical and experiential activities in Mathematics on mobile phones. In addition, the study also proposed an experience-oriented teaching situation according to the 2018 Education Program, through which students can access knowledge more proactively and dynamically. Due to the simplicity of both the design and application of situations to teach, this study can provide a new research direction to build and supplement the functions mentioned in the 2018 General Education Program in Mathematics.

References

Chesimet, M. C., Githua, B. N., & Ng'eno, J. K. (2016). Effects of experiential learning approach on students' mathematical creativity among secondary school students of Kericho East Sub-County, Kenya. *Journal of Education and Practice, 7*(23), 51-57.

Dang Thi, T. H. (2020). Tổ chức một số hoạt động trải nghiệm trong dạy học môn Toán cho học sinh Tiểu học [Organizing some experiential activities in teaching Mathematics for primary school students]. *Vietnam Journal of Education, Special issue 2* (May), 55-60.

Dias, G. N., de Oliveira, M. A. P., Chaquiam, M., Cabral, N. F., dos Reis, C. P., da Silva Barbosa, E, Araújo, J. C. O., Beirão, A. T. M., da Silva, K. P., da Rocha, H. O., de Melo Reis, N. D., & Barreto, W. D. L. (2021). Didactic sequence for teaching exponential function. *International Journal for Innovation Education and Research, 9*(8), 147-164.

Fabian, K., Topping, K. J., & Barron, I. G. (2018). Using mobile technologies for mathematics: effects on student attitudes and achievement. *Educational Technology Research and Development, 66*(5), 1119-1139. https://doi.org/10.1007/s11423-018-9580-3.

Fitriani, A., Zubaidah, S., Susilo, H., & Al Muhdhar, M. H. I. (2020). PBLPOE: A learning model to enhance students' critical thinking skills and scientific attitudes. *International Journal of Instruction, 13*(2), 89-106.

Fry, H., Ketteridge, S., & Marshall, S. (2009). *A handbook for teaching and learning in higher education: Enhancing academic practice* (3rd ed.). New York, USA: Routledge.

Kolb, A., & Kolb, D. (2009). Experiential learning theory: a dynamic, holistic approach to management learning, education and development. *In The SAGE Handbook of Management Learning, Education and Development* (pp. 42-68). SAGE Publications Ltd.

Le, T. B. T. T., Tran, D. K. (2021). Một số yếu tố tác động đến sự chấp nhận điện thoại thông minh trong dạy học của giáo viên Toán trung học [Some factors affecting the acceptance of smartphones in teaching by high school math teachers]. *Ho Chi Minh City University of Education Journal of Science, 18*(12), 2213-2220.

Makgakga, S. & Sepeng, P. (2013). Teaching and learning the mathematical exponential and logarithmic functions: A transformation approach. Mediterranean *Journal of Social Sciences, 4*(13), 177-185.

Ministry of Education and Training. (2018a). *Circular 32/2018/TT-BGDDT promulgating the General Education Program*. Ha Noi.

Ministry of Education and Training. (2018b). *The 2018 General Education Program in Mathematics*. Ha Noi.

Nguyen, N. G., Nguyen, T. N., Nguyen, V. D. (2022). Tổ chức hoạt động trải nghiệm trong dạy học nội dung "Một số yếu tố Thống kê" (Toán 6) [Organize experiential activities in teaching "Some statistics elements" (Math 6)]. *Vietnam Journal of Education, 22*(18), 1-6.

Nguyen, T. N., & Lam, T. T. (2023). Integrating financial education in teaching exponential functions for grade 12th students. *Ho Chi Minh City University of Education Journal of Science, 20*(3), 505–516. https://doi.org/10.54607/hcmue.js.20.3.3665(2023).

Nguyen, P. T., Ho, N. N. L. (2023). Dạy học nội dung "Thống kê" (Toán 7) thông qua hoạt động trải nghiệm [Teaching the content of "Statistics" (Mathematics 7th grade) through Experiential Activities]. *Vietnam Journal of Education, 23*(21), 1–6.

Nguyen, T. T. T., Quach, T. S. (2023). Some teaching methods for Statistics and Probability for 6th grade students with the support of information technology. *Vietnam Educational Science Journal, 19*(7), 27-34.

Nunes, L. F., Prates, D. B., & Silva, J. M. (2017). The use of modeling approach for teaching exponential functions. *Journal of Physics: Conference Series, 936*, 012064. https://doi.org/10.1088/1742-6596/936/1/012064

Rifa'i, A., & Sugiman, N. (2018). Students' perceptions of mathematics mobile blended learning using smartphone. *Journal of Physics. Conference Series, 1097*, 012153. https://doi.org/10.1088/1742-6596/1097/1/012153.

Sawalha, Y. (2018). *The Effects of Teaching Exponential Functions Using Authentic Problem Solving on Students' Achievement and Attitude* (Publication No. 10748542) [Doctoral dissertation, Wayne State University]. ProQuest Dissertations and Theses. https://www.proquest.com/dissertations-theses/effects-teaching-exponential-functions-using/docview/2030530682/se-2.

Sumandya, I. W., & Widana, I. W. (2022). Reconstruction of vocational-based mathematics teaching materials using a smartphone. *Journal of Education Technology, 6*(1), 133–139. https://doi.org/10.23887/jet.v6i1.42833

Tang, M. D., Trieu Thi, T., Nguyen Thi, N. (2021). Dạy học diện tích xung quanh của hình trụ theo tiếp cận học tập trải nghiệm [Teaching the surrounding area of the cylinder following an experiential learning approach]. *Ha Noi University of Education Journal of Science – Educational Sciences, 66*(3), 201–210.

Trinh, T. P. T., Lai, D. T., Hai, T. T., Trung, T., Le, T. T. T., Quan, H. V. (2019). Mobile learning for highschool mathematics as a path to better sustainability in a fast-changing society: An exploratory study from Vietnam. *Problems and Perspectives in Management, 17*(2), 392–403.

Tuda, S., & Rexhepi, S. (2023). Exploring exponential functions using geogebra. *Brillo Journal, 3*(1), 43–58. https://doi.org/10.56773/bj.v3i1.45

Umayah, U., & Riwanto, mawan A. (2020). Transforming 21st century elementary schools new digital literacy to build student character in a global era. *Jurnal Pancar, 4*(1), 1–10.

Veillon, J. (2019). *The Effect of Experiential Learning on Students' Conceptual Understanding of Functions in Algebra 1* [Doctoral Dissertation, Kennesaw State University]. DigitalCommons@Kennesaw State University. https://digitalcommons.kennesaw.edu/seceddoc_etd/15.

Venkatraman, S., Overmars, A., & Wahr, F. (2019). Visualization and experiential learning of mathematics for data analytics. *Computation, 7*(3), 37. https://doi.org/10.3390/computation7030037.

Vu, N. H., Nguyen, T. H., & Le, A. V. (2023). Một số vấn đề về tổ chức hoạt động thực hành và trải nghiệm trong dạy học môn Toán lớp 10 [Some problems in organizing practical and experiential activities in teaching 10th grade Mathematics]. *Vietnam Journal of Educational Sciences, 19*(1), 38–43.