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Creative Teaching in Mathematics: An Example in Linear Algebra

Saras Krishnan[1], Foo Kim Eng[2]

[1]School of Computing and Data Science, Xiamen University Malaysia, Bandar Sunsuria, 43900 Sepang, Malaysia, [2]Faculty of Engineering & Quantity Surveying, INTI International University Persiaran Perdana BBN, 71800 Nilai, Malaysia

Corresponding Author Email: saras.krishnan@xmu.edu.my

Email: kimeng.foo@newinti.edu.my

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Abstract

Creativity is an integral component in the current pedagogical approaches and curriculums. Creative thinking skills are developed over time and with accumulated competencies and experience. Especially with the global move in the direction of education from knowledge acquisition to competency development, creativity is central to educational curriculums. Being one of the higher order thinking skills, creativity serves as an intrinsic motivation to learn by giving learners freedom for exploration especially when supported by transformative technologies. In mathematics education, creative teaching enhances the development of learners' creative mathematical thinking and helps them to grasp difficult concepts more easily. Linear algebra is perceived as the more difficult subject in mathematics because it is associated with abstract concepts which are commonly memorized without comprehension. Moreover, students are not familiar with the applications of these concepts. In addition, students' lack of ability to think abstractly, to make connections. and to visualize the concepts and problems pose challenges in a linear algebra classroom. This paper discusses the use of MATLAB simulation to provide a creative learning experience for the students.

Keywords: Creative Thinking, Eigenvalues and Eigenvectors, Problem Solving, Simulation, Sustainable Development

Introduction

Education is an important instrument in achieving United Nation's Sustainable Development Goals, more so education that encourages creativity and innovation (Hensley, 2020; Nguyen et al., 2020). Creative skills are especially instrumental in a knowledge-based economy for the nation to progress (Khalid et al., 2020). Nguyen et al (2020) pointed out that apart from necessary content knowledge of the subject matter, other soft skills such as problem solving, creative thinking and critical thinking are imperative for sustainable development. When previously creativity was observed as an added and exceptional talent in a learner, the current educational curriculums warrant creativity to be one of the rudimentary skills to be acquired and developed by all learners (Wahyudi et al., 2020). Creative individuals possess the flexibility and connectivity required to approach problems differently and come up with innovative solutions (Hensley, 2020).

Creativity is closely linked with beliefs, feelings, thoughts and the needs of the learners. Creative thinking involves asking questions, forming new views, inter-relating and inter-connecting concepts, and using intuition (Rohaeti et al., 2019). According to Wahyudi et al. (2020), the ability to think creatively transpires from two essential attributes that are: (1) the learners' innate creative levels, and (2) the environment that provides opportunities for the development of the learners' creative thinking abilities. Creative thinking engages a learner's imagination and promotes the creation of original ideas (Hensley, 2020). Creative thinking involves functioning of the brain, memory, representation and manipulation in conjuring new knowledge, new approach, new perspective or new technique (Wahyudi et al., 2020). It is a mental activity that aids in formulating or solving problems, making decisions and attaining comprehension (Yayuk et al., 2020).

In mathematics learning, creative thinking is a component of the higher order thinking skills that enables learners to form new ideas and offer different solutions to complex mathematical problems (Hidajat, 2021). In fact, thinking creatively is the substance of mathematics education, say (Khalid et al., 2020). Mathematical concepts are mostly abstract and thus require high levels of cognitive activities (Serin, 2020). Mathematics train people to be logical, analytical, systematic, critical and creative (Putri & Saputro, 2019; Yayuk et al., 2020). According to Kozlowski et al (2019), mathematical creativity can be developed through the environment, teacher practice, years of education and exposure to complex mathematical problems.

Although creativity is a familiar conception related to the arts subjects, it is less common to emphasize creativity in the teaching of sciences and technical subjects, including mathematics (Khalid et al., 2020). Factors such as time constraint limit the use of creative support pedagogy and the stimulation of new ideas in learning mathematics (Hidajat, 2021; Schoevers et al., 2019). This paper discusses a technological aided creative pedagogy in teaching a concept of linear algebra that is eigenvalues and eigenvectors. Linear algebra is perceived as one of the more difficult courses in mathematics due to its abstract nature and the formal concepts (Moler & Little, 2020; Rensaa et al., 2022; Trigueros & Wawro, 2020). Learning of linear algebra requires higher order thinking skills and abstract thinking to make connections between the concepts. Creative approach in teaching linear algebra enables learners to visualize the concepts and to make connections between the concepts.

Literature Review

According to Anderson et al (2022), creativity in education consists of three components that are: (1) teaching for creativity, (2) teaching creatively, and (3) creative learning. Definition of creativity varies from being imaginative or inventive, to originality in thinking and in producing ideas (Khalid et al., 2020). For instance, Khalid et al (2020) defines creativity as the development of a set of attitudes that prompts the learners to become creative. Yayuk et al (2020) defines creative thinking as a cognitive function that refers to the ability to generate new ideas and concepts, and the ability to think divergently and productively in an academic domain. Meanwhile, Suryanto et al (2021) state that creative process can be understood at the micro level and at the macro level. Micro level involves the mechanisms underlying the creative process including the learners' thought process while macro level involves four stages of creative process which are awareness of thinking, observation of thinking, thinking strategy, and reflection of thinking.

Mathematical creativity is defined as the process of creating something new and meaningful by breaking away from established patterns or way of thinking (Schoevers et al., 2019). This means, mathematical creativity involves using cognition to combine learned concepts in an adequate but different manner therefore enhancing the understanding of mathematics (Schoevers et al., 2019). According to Wahyudi et al (2020), mathematics creative thinking is a combination of logical thinking and intuition based divergent thinking. Logical thinking is rational and coherent whereas divergent thinking uses logical thinking to be creative. Schoenfeld (2022) argues that it has been incorrectly assumed that mathematical proficiency is genetically influenced that is a student who is good in mathematics has inherited the genes associated with it. Instead, Schoenfeld (2022) argues that mathematical understanding can be improved through sensory engagement.

A systematic review of literature on mathematical creativity by Savic et al (2022) showed that mathematical contents mentioned in the articles were wide-ranging instead of focused on one topic or one area of mathematics. In addition, Joklitschke et al (2022) found that systematic literature review evidenced increasing interest in empirical studies involving creativity in mathematics education. In particular, the notion of mathematical creatively have been investigated from five important perspectives which are: (i) creativity as flexibility, fluency and other characteristics, (ii) creativity as divergent thinking, (iii) creativity as sequence of stages, (iv) creative mathematical reasoning, and (v) based on person, product, process and/or behaviour.

Rohaeti et al (2019) believe that creative thinking is not instinctive but can be developed through perseverance, self-discipline and mindfulness. In addition, Khalid et al. (2020) mention that creativity can be taught and can be nurtured through daily interactions in a creative environment. Thus, in the process of developing learners' creative skills, it is important to create a conducive environment for them to express their views unreservedly and share their experiences without being judged (Sharoff, 2019). In that sense, effective teaching and learning process is highly reliant on the instructor's ability in designing and delivering instructional materials that are creative and that are able to induce creativity thinking in the learners.

Literature also pointed out that to develop learners' mathematical creativity, the instructors or facilitators firstly must be creative and innovative themselves. In addition, it is important to give students' sufficient freedom to explore the mathematical concepts instead of restricting them to taught mathematical procedures (Schoevers et al., 2019; Sharoff, 2019). In that note, Anderson et al (2022) highlighted the significant benefit that students can gain if the instructors have imaginative, explorative and inquisitive personalities. It is thus crucial that delivery of lessons in mathematics are not confined to a dogmatic approach but the teaching and learning process is allowed to be open to uncertainties in order to encourage creative learning.

Apart from routine solutions to mathematical problems, mathematical creativity involves creating new and meaningful mathematical ideas or conceptions (Schoevers et al., 2019). However, researchers lament that even though mathematical problems can be approached in different ways, emphasis of mathematics education has been on content replication, students' grades, assessment systems and the curriculum objectives (Johansen et al., 2022). Mathematical pedagogical strategies are more focused on the mechanics of mathematics instead of on learners' creative thinking ability. As such, mathematics learners have very little opportunities to express their creativity in mathematics classrooms (Khalid et al., 2020).

Moreover, teachers lack the necessary knowledge, skills and classroom strategy to foster students' creativity (Kandemir et al., 2019).

An approach found to promote learners' development of critical thinking skills and creativity in mathematics is problem-based learning or PBL (Yunita et al., 2020). Learners develop mathematical creative thinking in a PBL activity especially when they conceive and create novel approaches in the problem-solving process (Khalid et al., 2020; Rohaeti et al., 2019). In the context of problem posing and problem solving, mathematical creativity is the process that results in innovative solutions to analogous problems and the emergence of new questions and possibilities that allows for a new perspective of the old problem (Schoevers et al., 2019). The development and implementation of new ideas in the problem-solving process involves creative thinking.

In general, researchers agree that mathematical aptitude is not an in-built ability and that mathematical learning can be improved and enhanced through creative pedagogical approaches (e.g., Schoenfeld, 2022). In fact, Shermukhammadov (2022) says that pedagogical activities are creative processes by themselves. In a creative educational setting, the instructor has less autonomy, adopts new skills and incorporates new technologies into the delivery of lessons. Other ways of cultivating mathematical creativity are to contextualize mathematics, that is to deliver a mathematics content in a language or form that can be understood by the learners and the use of technology as a learning tool (Ahn & Edwin, 2018; Wahyudi et al., 2020).

Technology is especially useful in changing abstract mathematical contents into concrete contents with the help of visual and audio enhancements (Serin, 2020). In this time and age, the introduction and addition of new pedagogical tools to the existing inventory are as rapid as with the innovations in technology and so educators can leverage on the strength of the pedagogy and technology to cultivate mathematics creative thinking skills (Serin, 2020). Researchers also found that technologically assisted lessons delivery in mathematics classrooms makes learning more enjoyable for the students and thus has positive impact on their overall attitudes towards learning mathematics (e.g., Abate et al., 2022; Jaafar et al., 2022).

This paper describes the use of MATLAB, acronym for the name Matrix Laboratory, in teaching the concepts of eigenvalues and eigenvectors at an undergraduate level. MATLAB was initially developed as a simple matrix calculator and has evolved to be a very powerful programming language having created over sixty toolboxes (Moler & Little, 2020). The graphics and animation feature of MATLAB have been found to greatly aid mathematics teaching, especially at the higher levels, by creating intuitive image for learners to understand abstract mathematical concepts thus stimulating their interest and reducing the perceived difficulties of learning mathematics (Zha, 2021).

MATLAB in a Linear Algebra classroom

It can be a challenge to teach the concepts of eigenvalues and eigenvectors particularly in connecting them to real-world examples and applications. Therefore, instructors must find creative ways to illustrate these concepts to the students and provide real-life examples that enable students to appreciate the significance of learning these mathematical concepts. A crucial property of eigenvectors of a square matrix A is that the direction remains the same under matrix multiplication. Additionally, these transformed vectors can exhibit an amplification or reduction in magnitude, maintain their orientation or reverse it.

In the vector space R^2, any vector $\boldsymbol{x}$ can be expressed as a linear combination of two linearly independent eigenvectors. This representation takes the form of $\alpha\boldsymbol{v}_1 + \beta\boldsymbol{v}_2$, where α and β denote scalars. By employing this approach, transformations can be simplified by utilizing the eigenvalue equation, as demonstrated here. Let $\boldsymbol{v}_1$ and $\boldsymbol{v}_2$ signify the eigenvectors of a 2×2 matrix A, corresponding to its eigenvalues λ_1 and λ_2, respectively. Consequently, the equation $A\boldsymbol{x} = A(\alpha\boldsymbol{v}_1 + \beta\boldsymbol{v}_2)$ can be established, resulting in $\alpha A\boldsymbol{v}_1 + \beta A\boldsymbol{v}_2$, which further simplifies to $\alpha\lambda_1\boldsymbol{v}_1 + \beta\lambda_2\boldsymbol{v}_2$.
The students are introduced to a simulation of a spring-mass system, created with MATLAB software, to exemplify the key concepts of eigenvalues and eigenvectors of 2×2 matrices, as well as the principle of the linear combination of vectors. Consider a mass-spring duo oscillation system, where m represents the masses of the boxes and k represents the spring constant for the three springs as illustrated in Figure 1.

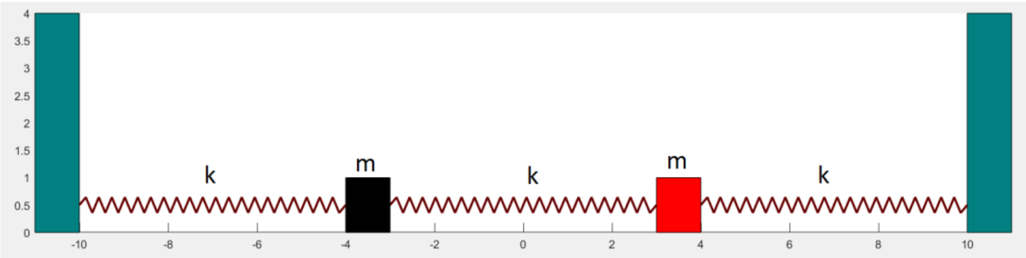

Figure 1
A mass-spring duo oscillation system

To allow oscillation, the masses are slightly displaced from their equilibrium positions. For example, the first and second boxes may be slightly displaced to the right by one unit and four units respectively as shown in Figure 2.

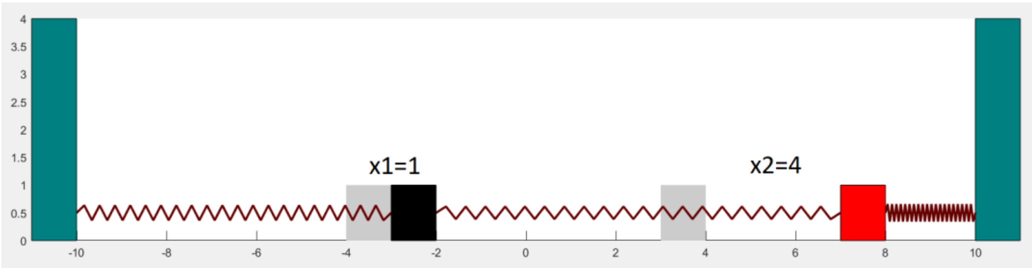

Figure 2
Displacement in the system

By analysing the force acting on the two masses, the following eigenvalue equation is derived:

$$\begin{pmatrix} 2k/m & -k/m \\ -k/m & 2k/m \end{pmatrix}\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \omega^2 \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} \tag{1}$$

where $\boldsymbol{x} = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix}$ signifies the displacement of the masses, and ω is the common frequency for both masses when the displacement vector, $\boldsymbol{x}$ is an eigenvector of the matrix $\begin{pmatrix} 2k/m & -k/m \\ -k/m & 2k/m \end{pmatrix}$. Without the loss of generality, all masses and spring constants can be considered as 1. Equation (1) can thus be simplified to:

$$\begin{pmatrix} 2 & -1 \\ -1 & 2 \end{pmatrix}\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \omega^2 \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} \tag{2}$$

Applying standard procedures, the eigenvalues can be calculated as $\omega^2 = 1$ or $\omega^2 = 3$, which implies that the angular frequencies for the initial displacements aligned with the two linearly independent eigenvectors are $\omega = 1$ and $\omega = \sqrt{3}$ respectively.
Students discover the eigenvectors for this simplified spring-mass system without calculations, using the criteria:
(i) for the displacement $\begin{pmatrix} x_1 \\ x_2 \end{pmatrix}$ to be an eigenvector, the resultant vector of $A\boldsymbol{x}$ must be proportional to $\boldsymbol{x}$ with one of the oscillation frequencies, say ω_1.
(ii) the displacements x_1 and x_2 must always keep a constant ratio between them throughout the oscillation.
(iii) the two masses should oscillate at the same frequency ω_1.

Instructors can then ask the students to suggest the correct displacement that fulfils this condition. After a few attempts, students are most likely to discover one of the correct answers is $x_1 = 1, x_2 = 1$. This finding can then be confirmed and demonstrated to students through a MATLAB-developed program that simulates a mass-spring pair oscillation. Using the values $x_1 = 1$ and $x_2 = 1$, the program will simulate the oscillation of two masses. The frequency is identical and the oscillations are in phase. The displacements of the boxes from the equilibrium point over time are illustrated in the screenshot shown in Figure 3.

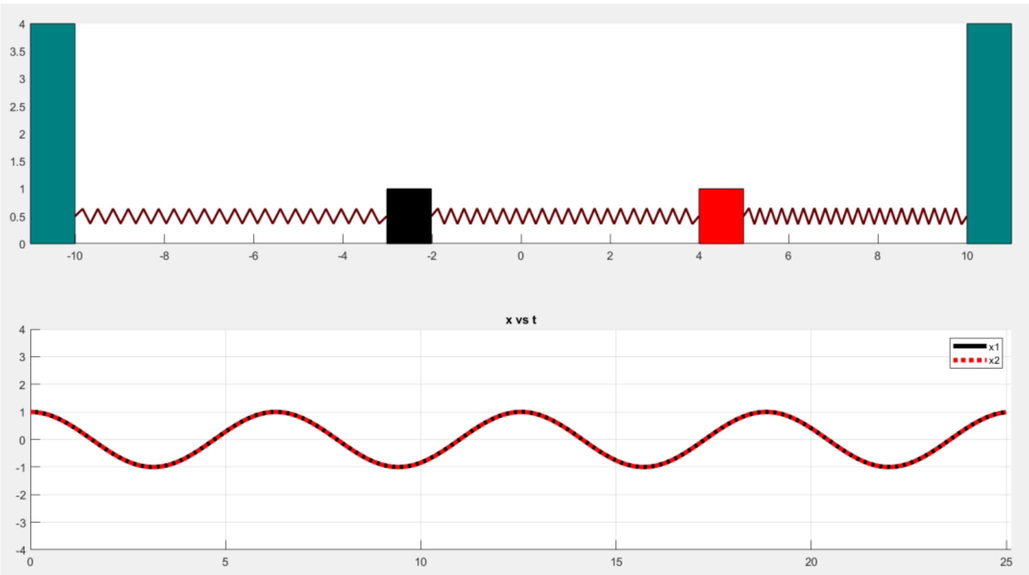

Figure 3
Simulation of the oscillation system for $x_1 = 1$ and $x_2 = 1$

Typically, for a 2×2 matrix, there are two sets of eigenvectors. Using the same criteria as before, students can deduce that the other eigenvector is $x_1 = 1$ and $x_2 = -1$ corresponding to the second angular frequency, denoted as ω_2. This conclusion can be validated using the same mass-spring pair oscillation program with $x_1 = 1$ and $x_2 = -1$. Their frequencies match and the oscillations are out of phase, as shown in the subsequent screenshot in Figure 4. From the simulation, it's evident that the frequency for the displacement of $x_1 = 1, x_2 = -1$ is higher than the displacement of $x_1 = 1$, $x_2 = 1$. This is an expected outcome as the angular frequency is $\omega = \sqrt{3}$ instead of $\omega = 1$. To demonstrate the concept that the result of applying matrix A to an arbitrary vector is the sum of the individual results of eigenvectors acted upon by the same matrix, this time let the displacement to be $x_1 = 1$, $x_2 = 4$.

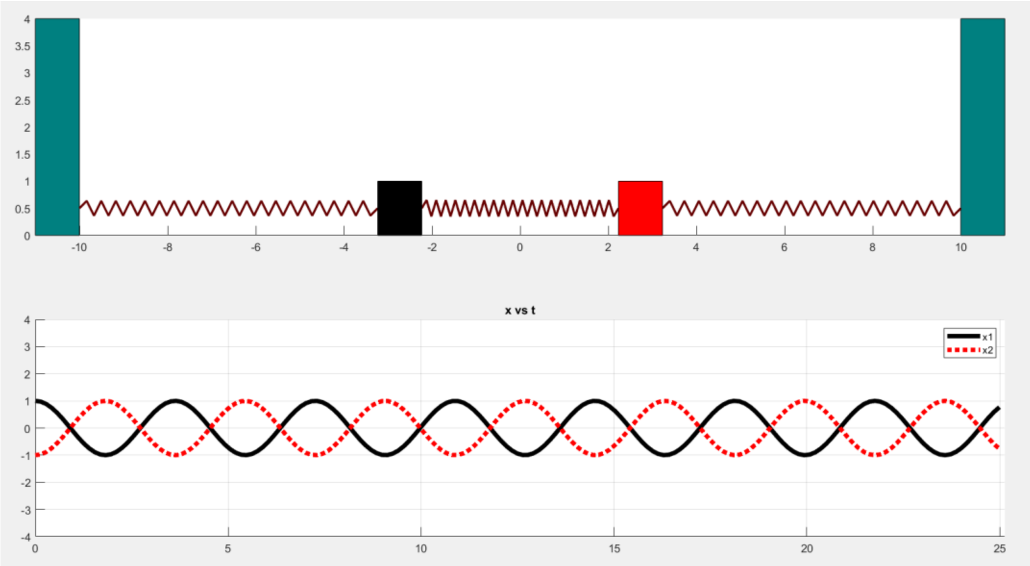

Figure 4
Simulation of the oscillation system for $x_1 = 1$ and $x_2 = -1$

This displacement $\binom{1}{4}$ can be viewed as the linear combination of the eigenvectors given as:

$$\binom{1}{4} = 2.5\binom{1}{1} + (-0.5)\binom{1}{-1} \tag{3}$$

Thus, the resultant oscillation due to the initial displacement $\binom{1}{4}$ can be obtained by simply adding the oscillations caused by the initial displacements 2.5 $\binom{1}{1}$ and (-0.5)$\binom{1}{-1}$. With the input $x_1 = 1$ and $x_2 = 4$, the MATLAB simulation program shows the oscillation of two masses with initial displacement $x_1 = 1$, $x_2 = 4$, by simply adding the oscillations caused by $2.5\binom{1}{1}$ and $(-0.5)\binom{1}{-1}$. The screenshot of the resulting oscillation is shown in Figure 5. The graphs depict the displacement versus time for both the boxes. The oscillations are no longer purely sinusoidal, as they are superpositions of two sinusoids with different frequencies and magnitudes.

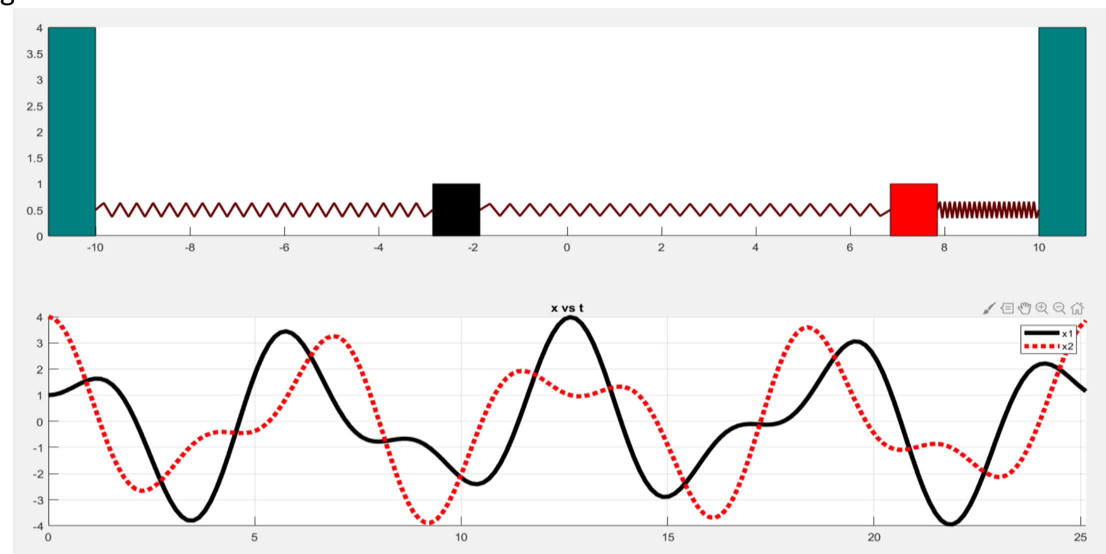

Figure 5
Simulation of the oscillation system for $x_1 = 1$ and $x_2 = 4$

Discussion

Past studies show significant correlations between creative thinking skills and learners' achievement. However, there are dissuading perceptions that creativity and mathematics do not go together because mathematics involves algorithms and procedures. Perhaps this is true to some extent as the somewhat fixed nature of the solution steps and procedures do not give learners much room to think creatively. To overcome this, it is important to move away from the traditional approach of teaching mathematics to more application based real-life problems. The example discussed in this paper is a simulation that provides a hands-on and visual method for students to understand the abstract concepts of eigenvectors and eigenvalues. It aids in developing students' creative thinking through these factors:

(1) Real-world Connections

It maps abstract mathematical concepts to a real-world application that is a spring-mass system. Demonstrating the application of these concepts to physical systems that students can observe and relate to makes these ideas more concrete for them.

(2) Visual Representation

The simulation depicts the behavior of the system visually, enabling students to see the impact of the mathematical transformations, rather than merely doing the calculations. This appeals to visual learners and can help them develop a more intuitive understanding.

(3) Reinforces Theory with Practice

The simulation uses actual equations of motion that students encounter in their theory lessons. By seeing these equations in action, students can better appreciate their significance and relevance.

(4) Understanding Linear Combinations

By changing the initial conditions (displacements) and observing the resultant oscillations, students can see how any given state can be expressed as a linear combination of the eigenvectors. This vividly illustrates a core principle in linear algebra.

(5) Introduction to Computational Tools

The use of MATLAB, a widely used software in various scientific and engineering fields, provides students with practical computational skills that will be beneficial for their future studies and careers.

In conclusion, this simulation serves as a bridge between abstract concepts of linear algebra and their practical applications, aiding in the comprehension and retention of the subject matter. However, this is only a first step to understanding the full range of applications for these concepts. The principles of eigenvalues and eigenvectors extend far beyond simple physical systems, impacting fields as diverse as quantum physics, economics, computer science, and engineering. Researchers have pointed out the importance of mathematical creativity in tertiary education before students began their careers. More importantly, by using creative pedagogical approaches in mathematics classrooms, the abstract mathematical concepts can be more easily grasped and understood by learners.

Author Contributions

All authors have sufficiently contributed to the study.

Declaration of Interest

No conflict of interest is declared by authors.

References

Abate, A., Atnafu, M., & Michael, K. (2022). Visualization and Problem-Based Learning Approaches and Students' Attitude toward Learning Mathematics. *Pedagogical Research*, *7*(2). https://doi.org/10.29333/pr/11725

Ahn, J. Y., & Edwin, A. (2018). An e-learning model for teaching mathematics on an open-source learning platform. *International review of research in open and distributed learning*, *19*(5). https://doi.org/10.19173/irrodl.v19i5.3733

Anderson, R. C., Katz-Buonincontro, J., Bousselot, T., Mattson, D., Beard, N., Land, J., & Livie, M. (2022). How am I a creative teacher? Beliefs, values, and affect for integrating creativity in the classroom. *Teaching and Teacher Education*, *110*, 103583. https://doi.org/10.1016/j.tate.2021.103583

Hensley, N. (2020). Educating for sustainable development: Cultivating creativity through mindfulness. *Journal of Cleaner Production*, *243*, 118542. https://doi.org/10.1016/j.jclepro.2019.118542

Hidajat, F. A. (2021). Students Creative Thinking Profile as a High Order Thinking in the Improvement of Mathematics Learning. *European Journal of Educational Research*, *10*(3), 1247-1258. https://doi.org/10.12973/eu-jer.10.3.1247

Jaafar, N., Nor, S. R. M., Norrulashikin, S. M., Kamisan, N. A. B., & Mohamad, A. Q. (2022). Increase students' understanding of mathematics learning using the technology-based learning. *International Journal of Advanced Research in Future Ready Learning and Education*, *28*(1), 24-29.

Johansen, A., Mogstad, E., Gajic, B., & Bungum, B. (2022). Incorporating creativity in science and mathematics teaching: Teachers' views on opportunities and challenges. *Nordic Studies in Science Education*, *18*(1), 98-111. https://doi.org/10.5617/NORDINA.8620

Joklitschke, J., Rott, B., & Schindler, M. (2022). Notions of Creativity in Mathematics Education Research: A Systematic Literature Review. *International Journal of Science and Mathematics Education*, *20*(6), 1161-1181. https://doi.org/10.1007/s10763-021-10192-z

Kandemir, M. A., Tezci, E., Shelley, M., & Demirli, C. (2019). Measurement of creative teaching in mathematics class. *Creativity Research Journal*, *31*(3), 272-283. https://doi.org/10.1080/10400419.2019.1641677

Khalid, M., Saad, S., Hamid, S. R. A., Abdullah, M. R., Ibrahim, H., & Shahrill, M. (2020). Enhancing creativity and problem-solving skills through creative problem solving in teaching mathematics. *Creativity Studies*, *13*(2), 270-291. https://doi.org/10.3846/cs.2020.11027

Kozlowski, J. S., Chamberlin, S. A., & Mann, E. (2019). Factors that influence mathematical creativity. *The Mathematics Enthusiast*, *16*(1), 505-540. https://doi.org/10.54870/1551-3440.1471

Moler, C., & Little, J. (2020). A history of MATLAB. *Proceedings of the ACM on Programming Languages*, 4(HOPL), 1–67. https://doi.org/10.1145/3386331

Nguyen, T. P. L., Nguyen, T. H., & Tran, T. K. (2020). STEM education in secondary schools: Teachers' perspective towards sustainable development. *Sustainability*, *12*(21), 8865. https://doi.org/10. 3390/su12218865

Putri, M. E., & Saputro, D. R. S. (2019). The effect of application of REACT learning strategies on mathematics learning achievements: Empirical analysis on learning styles of junior high school students. *International Journal of Educational Research Review*, *4*(2), 231-237.
https://doi.org/10.24331/ijere.518065

Rensaa, R. J., Hogstad, N. M., & Monaghan, J. (2020). Perspectives and reflections on teaching linear algebra. *Teaching Mathematics and its Applications: An International Journal of the IMA*, *39*(4), 296-309.
https://doi.org/10.1093/teamat/hraa002

Rohaeti, E. E., Nurjaman, A., Sari, I. P., Bernard, M., & Hidayat, W. (2019, February). Developing didactic design in triangle and rectangular toward students mathematical creative thinking through Visual Basic for PowerPoint. *Journal of Physics: Conference Series*, 1157(4).
https://doi.org/10.1088/1742-6596/1157/4/042068

Savić, M., Satyam, V. R., El Turkey, H., & Tang, G. (2022). Mathematical Creativity at the Tertiary Level: A Systematic Review of the Literature. In S. A. Chamberlain, P. Liljedahl & M. Savic (Eds.), *Mathematical Creativity: A Developmental Perspective* (pp. 105-120). Springer.
https://doi.org/10.1007/978-3-031-14474-5

Schoenfeld, A.H. (2022). Why Are Learning and Teaching Mathematics So Difficult? In: Danesi, M. (eds) *Handbook of Cognitive Mathematics*. Springer, Cham. https://doi.org/10.1007/978-3-030-44982-7_10-1

Schoevers, E. M., Leseman, P. P., Slot, E. M., Bakker, A., Keijzer, R., & Kroesbergen, E. H. (2019). Promoting pupils' creative thinking in primary school mathematics: A case study. *Thinking skills and creativity*, *31*, 323-334.
https://doi.org/10.1016/j.tsc.2019.02.003

Serin, H. (2020). The impact of technology-aided instruction on motivation of geometry learners. *International Journal of Social Sciences & Educational Studies*, *7*(3), 63-72.
https://10.23918/ijsses.v7i3p63

Sharoff, L. (2019). Creative and innovative online teaching strategies: Facilitation for active participation. *Journal of Educators Online*, *16*(2), n2.
https://files.eric.ed.gov/fulltext/EJ1223934.pdf

Shermukhammadov, B. (2022). Creativity of a Teacher in an innovative educational environment. *Journal of Higher Education Theory and Practice*, *22*(12).

Suryanto, H., Warring, S., Kartikowati, R. S., Rorimpandey, W. H., & Gunawan, W. (2021). Study creativity with diverse social skills to support the learning process in future education. *Journal of diversity in learning (JDIL)*, *1*(2), 85-89.
https://www.journalofdiversity.com/index.php/jdil/article/view/21

Trigueros, M., & Wawro, M. (2020). Linear Algebra Teaching and Learning. In S. Lerman (Ed.), *Encyclopedia of Mathematics Education* (pp. 474–478). Springer International Publishing.
https://doi.org/10.1007/978-3-030-15789-0_100021

Wahyudi, W., Waluya, S. B., Suyitno, H., & Isnarto, I. (2020). The impact of 3CM model within blended learning to enhance students' creative thinking ability. *JOTSE: Journal of Technology and Science Education*, *10*(1), 32-46. https://doi.org/10.3926/jotse.588

Yayuk, E., Purwanto, As'ari, A. R., & Subanji. (2020). Primary school students' creative thinking skills in mathematics problem solving. *European Journal of Educational Research*, *9*(3), 1281-1295. https://doi: 10.12973/eu-jer.9.3.1281

Yunita, Y., Juandi, D., Tamur, M., Adem, A. M. G., & Pereira, J. (2020). A meta-analysis of the effects of problem-based learning on students' creative thinking in mathematics. *Beta: Jurnal Tadris Matematika*, *13*(2), 104-116. https://doi.org/10.20414/betajtm.v13i2.380

Zha, X. (2021). Application of MATLAB Software in Higher Mathematics Teaching. In *International Conference on Forthcoming Networks and Sustainability in the IoT Era* (pp. 261-266). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-99581-2_37