J-IAMSTEM
Journal of Innovation, Advancement, and Methodology in STEM Education
Vol. 2, No. 3, pp. 168-175, May-June 2025
https://so13.tci-thaijo.org/index.php/j_iamstem

Educational Tool for Simultaneously Teaching Link Mechanism and Power Generation: A Pilot Study of STEM Education using LEGO

Kodai Kitagawa[1*], Kyosuke Taguchi[1], Enke Haoribao[1], Masaaki Yoshida[2]
[1]Department of Industrial Systems Engineering, National Institute of Technology (KOSEN), Hachinohe College, Japan
[2]Department of General Science and Education, National Institute of Technology (KOSEN), Hachinohe College, Japan
*Corresponding author email: kitagawakitagawa156@gmail.com

Received: 9 May 2025 Revised: 29 May 2025 Accepted: 18 June 2025

Abstract

Link mechanisms and power generation are important topics in engineering education. Previous studies have used educational tools for either link mechanisms or power generation. However, to the best of our knowledge, there is no tool that can provide education on both link mechanisms and power generation. Additionally, STEM (science, technology, engineering, and mathematics) education with multiple interdisciplinary topics is required to train engineers with advanced skills. The objective of this study was to develop and evaluate an educational tool for simultaneously teaching both link mechanisms and power generation through STEM workshop. The proposed tool was implemented using LEGO to discover students' creativity. The proposed tool was evaluated via an educational workshop on link mechanisms and power generation, with 17 students as participants. The participants were asked to answer questions about their enjoyment and understanding of the workshop using a visual analogue scale (VAS) with 100 mm segments. The results showed that average values of VAS scores for enjoyment and understanding were at least almost 80 mm. The results of the VAS scores showed that participants could understand both the link mechanisms and power generation via workshop using the proposed tool. In addition, the VAS scores indicated that the participants enjoyed the workshop. Furthermore, participants could design and implement the original link mechanisms based on their creativity in the workshop. These results suggest that the proposed tool using LEGO can provide effective and motivative education for both link mechanisms and power generation. Moreover, the proposed tool using LEGO might be suitable for STEM education and future creative STEAM (science, technology, engineering, art, and mathematics) education because it can provide a chance for designing original link mechanisms.

Keywords: Link mechanism, Power generation, LEGO, STEM education, STEAM education

1. Introduction

The link mechanism is an important basic mechanical mechanism for education in various engineering fields such as mechanical, electrical, and production engineering (Bolger et al., 2009; Ling-Lin et al., 2012; Wang et al., 2016; Yang et al., 2015). Previous studies have reported that computational application and LEGO contributed to training link mechanisms, such as four-bar linkage (Isoda & Matsuzaki, 1999; Matsuzaki, 2010; Yu & Gong, 2021). Based on these reports, this study focused on LEGO as an effective tool for education in link mechanisms. Power generation is also an important topic because the experience and knowledge of energy translation, including power generation, are necessary for training theoretical and practical electrical engineers (Chai et al., 2021; Fiandini et al., 2024; Gong et al., 2022; Opriş et al., 2021). Previous studies have provided educational tools using power generation technology, such as dynamos (García-Ferrero et al., 2021; Yamamoto et al., 2008).

As mentioned previously, several studies have used educational tools for either link mechanisms or power generation. However, to the best of our knowledge, there is no tool that can provide education on both link mechanisms and power generation. Recently, STEM (science, technology, engineering, and mathematics) education with multiple interdisciplinary topics has been required for training engineers who have advanced skills (Akgunduz & Mesutoglu, 2021). Given this background, further educational tools for interdisciplinary multiple topics will be required for STEM education. As indicated earlier, this study focused on LEGO for developing educational tool. Previous studies indicated that LEGO could be applied various STEM educations related to robotics, engineering, physics, and mathematics (Addido et al., 2023; Graffin et al., 2022; McGrath et al., 2009). Thus, there is possibility that LEGO is suitable for educational tool of STEM education about both link mechanisms and power generation too.

The objective of this study is to develop and evaluate an educational tool using LEGO for simultaneously teaching both link mechanisms and power generation through a STEM workshop. This study provides an experience for STEM education as a pilot study.

2. Methodology

2.1 Proposed Tool and Workshop

As previously mentioned, LEGO was used to train link mechanisms, such as the four-bar linkage (Isoda & Matsuzaki, 1999; Matsuzaki, 2010). In addition, the LEGO motor was used as a dynamo in a previous study (Piper & Ishii, 2002). Based on these previous studies, the proposed tool was developed using link mechanisms and dynamo, which were made using LEGO.

Table 1 lists the topics of each lesson in the educational workshop using the proposed tool. Examples of materials (PowerPoint slides including LEGO photos) for each lesson are shown in Figure 1, 2, 3, and 4. In the first lesson, students were trained in truss using the proposed tool. Students can create and try truss using LEGO. In addition, educators provide knowledge of buildings using truss such as the Eiffel Tower. In the second lesson, students were trained in the lever crank mechanism using the proposed tool. Students can try to move lever crank mechanisms using LEGO. In the third lesson, students learned and experienced dynamo-based power generation using two interconnected LEGO motors. One LEGO motor was used as the hand crank for power generation. The rotation of the connected LEGO motor is used for visualizing the generated energy. Using these LEGO motors, students can experience the energy translation of power generation. In the fourth lesson, students tried to create original mechanisms by combining lever crank mechanisms and dynamos. Finally, students can operate lever-crank mechanisms using the energy obtained from dynamo-based power generation. From these four lessons, the students can learn both link mechanisms and power generation using the proposed tool. This workshop with these four lessons required approximately two hours.

Table1. Topics of Educational Workshop using the Proposed Tool

Lesson	Topic
1st	Truss (Link Mechanism)
2nd	Lever Crank as Four-bar Linkage (Link Mechanism)
3rd	Dynamo-based Power Generation
4th	Creating Original Mechanisms using Lever Crank and Dynamo

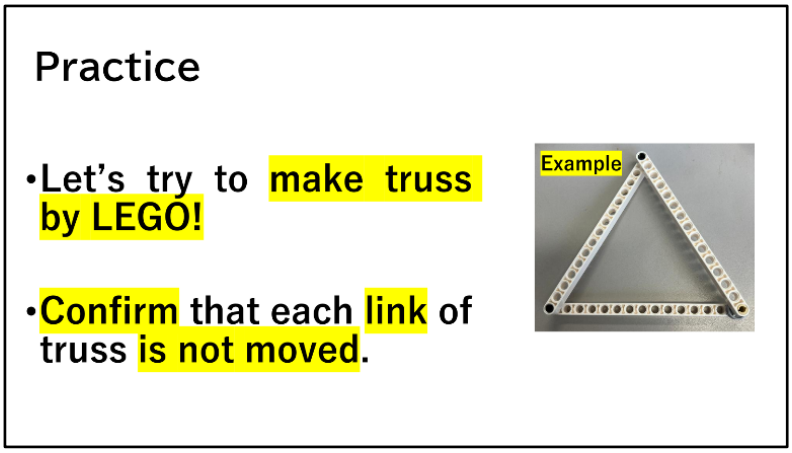

Figure 1. Example of Material in Lesson for Truss

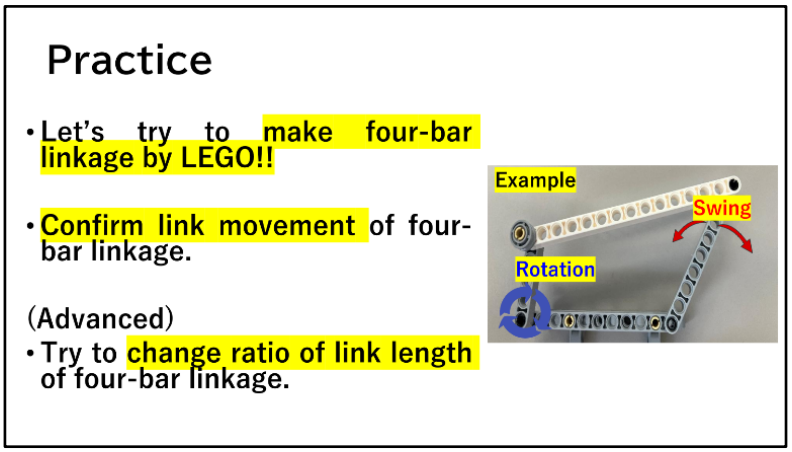

Figure 2. Example of Material in Lesson for Lever Crank

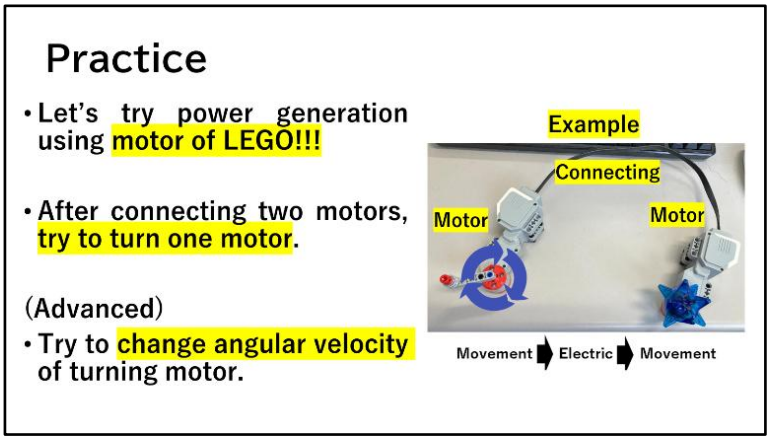

Figure 3. Example of Material in Lesson for Power Generation

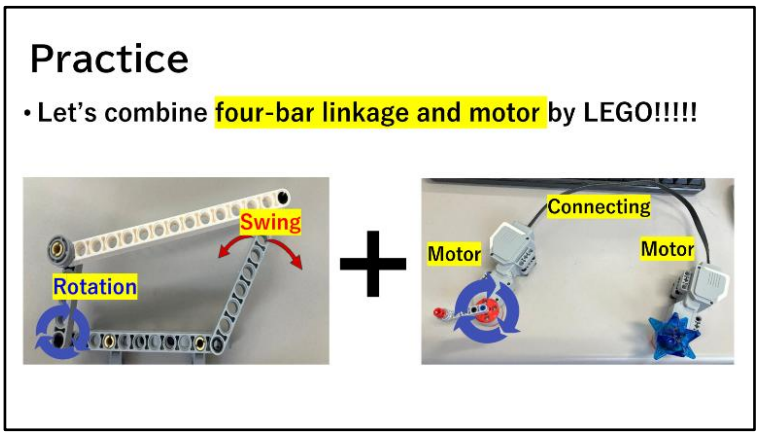

Figure 4. Example of Material in Lesson for Creating Original Mechanism

2.2 Evaluation of Proposed Tool via Workshop

The proposed tool was evaluated using the educational workshop described in the previous section. This workshop was conducted as a part of"KOSEN Global Camp 2025 in Hachinohe" that is short-term educational programs for training international engineers. The 17 college students including exchange students participated in the workshop. We had experience with international educational workshops for exchange students (Haoribao et al., 2024). Photographs of the educational workshop using the proposed tool are shown in Figure 5. Note that "KOSEN Global Camp 2025 in Hachinohe" was financially supported by the Sakura Science Exchange Program of the Japan Science and Technology Agency (JST).

After the workshop, students were asked to answer questions about their enjoyment and understanding of the workshop by visual analogue scale (VAS) with 100 mm segment. Figure 6 shows the questionnaire using the VAS. This questionnaire had five questions (Q1–Q5) and VAS segments for each question. In this questionnaire, higher scores indicated a positive feeling of enjoyment, understanding, or comfortability.

Figure 5. Photographs of Educational Workshop

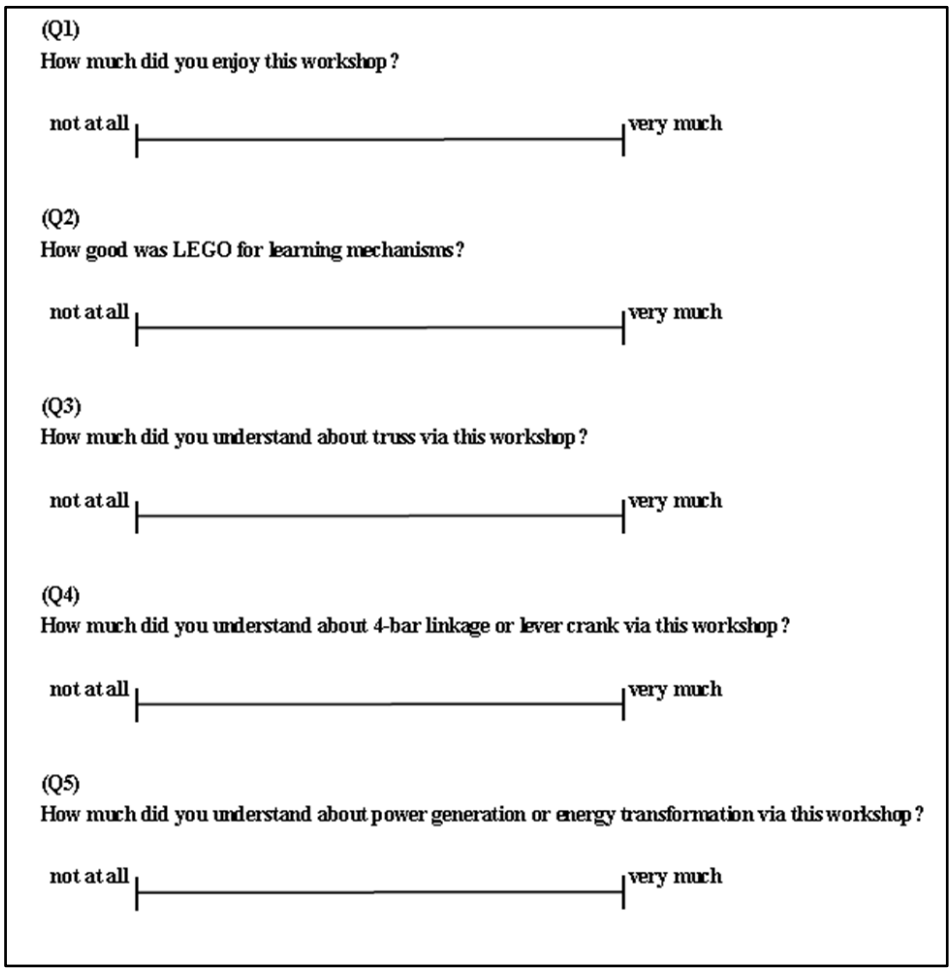

Figure 6. Questionnaire with VAS Segments

3. Results and Discussion

Figure 7 shows the VAS scores obtained from the questionnaire. The results showed that average values of VAS scores for enjoyment and understanding were at least almost 80 mm. The results of the high VAS scores for Q1 indicated that students enjoyed educational workshops using the proposed tool. In addition, the results of the high VAS scores of Q2 suggest that LEGO is suitable for education in mechanisms. Furthermore, the results of the high VAS scores of Q3, Q4, and Q5 suggested that the proposed educational tool could contribute to understanding both link mechanisms and power generation. These results about enjoyment and understanding show that the proposed educational tool using LEGO is suitable for simultaneously teaching both link mechanisms and power generation in STEM workshops.

Figure 8 shows photographs of the original mechanisms created by the students and educators. These link mechanisms can be moved by the electric energy obtained from the dynamo-based power generation. These results indicate that the proposed tool can provide an opportunity for designing original link mechanisms. Recently, STEM education has been extended to STEAM (science, technology, engineering, art and mathematics) education for training creativity (Conradty & Bogner, 2020; Guyotte et al., 2014; Niu & Cheng, 2022). From this background, it is considered that the proposed tool will contribute to future STEAM education for creativity because it can provide opportunities for creating original mechanisms.

Limitations of this study were small sample size and lack of objective performance assessments. In addition, this study could not investigate differences in understanding and enjoyment of workshops between the genders, ages, or departments of students because the sample size was small. Furthermore, this study could not consider students' experiences with LEGO were not considered in the investigation.

In future, the proposed tool and workshop should be evaluated and modified for various people and situations with larger sample size. Moreover, effects of the proposed tool should be evaluated by objective performance such as examination scores. Additionally, the proposed tool will cover additional mechanical mechanisms, such as gears. The proposed modified tool may contribute to future STEAM education for advanced and creative engineers.

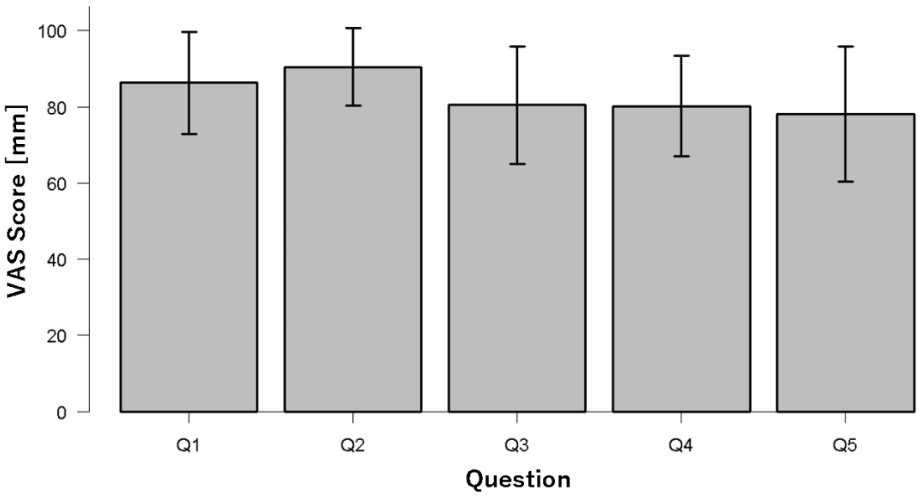

Figure 7. Results of VAS Scores in Questionnaire (Mean ± S.D.)

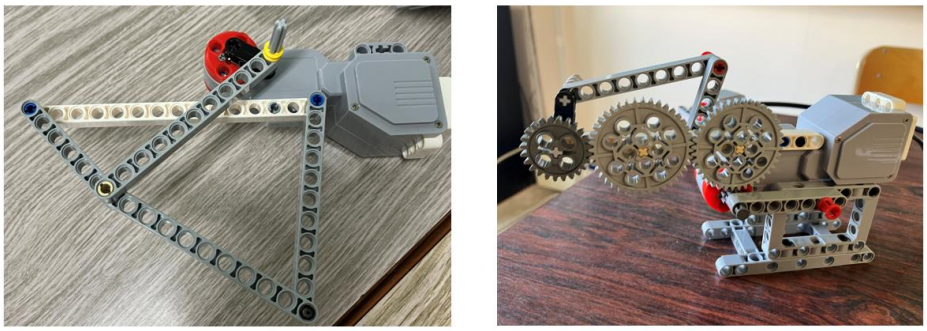

Figure 8. Examples of Created Mechanisms

4. Conclusion

In this study, we developed and evaluated an educational tool to simultaneously teach link mechanisms and power generation using LEGO. The results suggest that the proposed LEGO tool can provide effective and motivative education for both link mechanisms and power generation. In the future, the proposed tool can be used for STEM and STEAM education on mechanical mechanisms and power generation.

5. Acknowledgment

The educational workshop of this study was conducted in "KOSEN Global Camp 2025 in Hachinohe" which was financially supported by the Sakura Science Exchange Program of the Japan Science and Technology Agency (JST).

6. References

Addido, J., Borowczak, A. C., & Walwema, G. B. (2023). Teaching Newtonian physics with LEGO EV3 robots: An integrated STEM approach. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(6), em2280.

Akgunduz, D., & Mesutoglu, C. (2021). STEM education for Industry 4.0 in technical and vocational high schools: Investigation of teacher professional development. *Science Education International*, 32(2), 172–181.

Bolger, M., Kobiela, M., Weinberg, P., & Lehrer, R. (2009). Analysis of children's mechanistic reasoning about linkages and levers in the context of engineering design. 2009 *Annual Conference & Exposition*, ID:14.214.

Chai, H., Ravishankar, J., Meng, K., & Priestley, M. (2021). Improved Power Engineering Curriculum: Analysis in a Year 3 Course in Electrical Engineering. 2021 *IEEE Global Engineering Education Conference (EDUCON)*, 701–705.

Conradty, C., & Bogner, F. X. (2020). STEAM teaching professional development works: Effects on students' creativity and motivation. *Smart Learning Environments*, 7(1), 26.

Fiandini, M., Hofifah, S. N., Ragadhita, R., & Nandiyanto, A. B. D. (2024). How to make a cognitive assessment instrument in the merdeka curriculum for vocational high school students: A case study of generating device materials about the stirling engine. *ASEAN Journal for Science Education*, 3(1), 65–86.

García-Ferrero, J., Merchán, R. P., Roco, J. M. M., Medina, A., & Santos, M. J. (2021). Towards a sustainable future through renewable energies at secondary school: An educational proposal. *Sustainability*, 13(22), 12904.

Gong, W., Deng, F., Wang, X., & Chen, F. (2022). Discussion on the Reconstruction of Electrical Engineering Undergraduate Teaching Scheme Facing the New Generation Power System. *Frontiers in Energy Research*, 10, 880444.

Graffin, M., Sheffield, R., & Koul, R. (2022). 'More than Robots': Reviewing the Impact of the FIRST® LEGO® League Challenge Robotics Competition on School Students' STEM Attitudes, Learning, and Twenty-First Century Skill Development. *Journal for STEM Education Research*, 5(3), 322–343.

Guyotte, K. W., Sochacka, N. W., Costantino, T. E., Walther, J., & Kellam, N. N. (2014). Steam as Social Practice: Cultivating Creativity in Transdisciplinary Spaces. *Art Education*, 67(6), 12–19.

Haoribao, E., Yoshida, M., Maruoka, A., Kusakari, A., Kikuchi, A., Mawatari, T., & Nejo, K. (2024). Bridging Cultures and Engineering Minds: An International Exchange Program in Hachinohe. *Proceedings of the 19th International Symposium on Advances in Technology Education (ISATE 2024)*, 1–16.

Isoda, M., & Matsuzaki, A. (1999). Mathematical Modeling in the Inquiry of Linkages Using LEGO and Graphic Calculator. Does New Technology Alternate Old Technology? *Proceedings of the Forth Asian Technology Conference in Mathematics*, 113–122.

Ling-Lin, C., Qi, C., & Jiacheng, Z. (2012). Application of Delphi Software in the Teaching of Basics of Mechanical Design. In L. Zhang & C. Zhang (Eds.), *Engineering Education and Management* (Vol. 112, pp. 443–447). Springer Berlin Heidelberg.

Matsuzaki, A. (2010). Mathematical modelling in making linkages or mechanics: Using LEGO located on elementary mechatronics tools. *EIMI* 2010, 1–9.

McGrath, E., Lowes, S., Lin, P., & Sayres, J. (2009). Analysis of middle and high school students' learning of science, mathematics, and engineering concepts through a Lego underwater robotics design challenge. *2009 Annual Conference & Exposition*, 14–215.

Niu, W., & Cheng, L. (2022). Creativity and innovation in STEAM education. *Frontiers in Education*, 7, 1045407.

Opriş, I., Gogoaşe Nistoran, D. E., Costinaş, S., & Ionescu, C. S. (2021). Rethinking power engineering education for Generation Z. *Computer Applications in Engineering Education*, 29(1), 287–305.

Piper, B., & Ishii, H. (2002). PegBlocks: A learning aid for the elementary classroom. CHI '02 Extended Abstracts on Human Factors in Computing Systems, 686–687.

Wang, L.-W., Zhao, F., Du, W.-L., Luo, G.-F., Meng, F.-N., & LI, H.-W. (2016). Teaching reform and practice of the curriculum of mechanism design based on innovation ability training. *2016 3RD International Conference on Advanced Education and Management (ICAEM 2016)*, 474–479.

Yamamoto, T., Ogikubo, K., & Nishimura, T. (2008). Development of the teaching tool to learn the mechanism of wind power generation. *The International Conference on Business & Technology Transfer* 2008.4, 28–33.

Yang, Q., Dai, P., Yu, T., Sun, Z., Yan, Y., & Shen, P. (2015). Teaching Reform for Curriculum Design of Mechanisms and Machines Theory Focusing on Students' Practice and Innovation Abilities. *2015 Conference on Education and Teaching in Colleges and Universities*, 104–107.

Yu, Z., & Gong, J. (2021). Utilizing computational tools to enhance student's understanding of linkage mechanism. *2021 Fall ASEE Middle Atlantic Section Meeting*, 1–12.